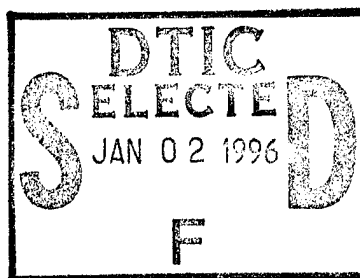


TEC-0068

Spectral Signatures Of Wetlands Plants (350-900nm)



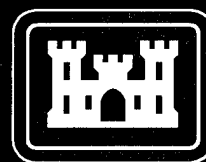
John E. Anderson

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August 1995

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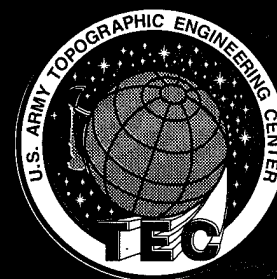


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PREFACE

This report was funded under DA Project 4A161102B52C, Task C, Work Unit 010.

This study was done under the supervision of Dr. Jack N. Rinker and Mr. J.V.E. Hansen, Chief, Remote Sensing Laboratory, Spectral Research Division.

Mr. Walter E. Boge was Director and LTC Louis DeSanzo was Commander and Deputy Director of the Topographic Engineering Center at the time of publication of this report.

SPECTRAL SIGNATURES OF WETLAND PLANTS

INTRODUCTION

This spectral report, which is to be used as an addendum along with the Engineer Topographic Laboratories publication "Hyperspectral Signatures (400 to 2500 nm) of Vegetation, Minerals, Soils, and Cultural Features: Laboratory and Field Measurements" (*Satterwhite and Henley, 1990*), expands the vegetation portion of the catalogue to include wetlands plant species. This report enables ecologists, resource managers and terrain specialists the opportunity to examine the spectral signatures of various wetlands plant species and to use them as a guide when making decisions about sensor band pass selection.

Wetland ecotones are unique in that they are the interface of totally aquatic systems and terrestrial systems. Remote sensing has been used for many years to characterize the zonation of plant communities associated with wetlands, but spectral data has not been used extensively to program band passes to detect aquatics, grasses, sedges, rushes, and wetland trees and shrubs. Historically, experiments on wetland plant detection based on spectra was reported by Wenderoth *et. al* (1972) using multispectral photography. Additionally, the U.S. Army Corps of Engineer's Waterways Experiment Station collected limited data on plant spectra within the Aquatic Plant Control Program. Both efforts are examples of attempting to understand the spectral reflectance differences exhibited by plants due to their structure and landscape position.

This Spectral Signatures of Wetland Plants report is an attempt to catalogue the major plant communities associated with different wetlands (coastal, estuarine, riverine, pallustrine, lacustrine) in an effort to characterize spectrally the zonation patterns which are closely tied to topography, hydrology and hydric soil development. With the future development of the hydrogeomorphic approach to wetlands classification, remote sensing strategies will have to be generated to provide accurate spectral and spatial classifications of the landscape.

The increasing spectral and spatial fidelity of newer generation sensors requires detailed knowledge of the spectroradiometric characteristics of wetland plants. For example, in Figure 1 the spectral reflectance is presented of two species of cattail - *Typha latifolia* and *Typha angustifolia*. The spectral characteristics of these two species are quite different. As the figure indicates, *Typha l.* is brighter in the green portion of the spectrum (550 nm) and much brighter in the infrared portion of the spectrum (770 nm). The dichotomy of the two signatures is due in part to specific leaf morphology that is unique to each species. With particular attention to the infrared region (770 to 850nm), the differences seen in broad-leaf and narrow-leaf cattails may be

explained as a function of leaf area and intercellular biomass. The latter is governed by cell shape and size as well as the size of the intercellular spaces, which changes during different levels of maturity (Gates *et al.*, 1965).

METHODS

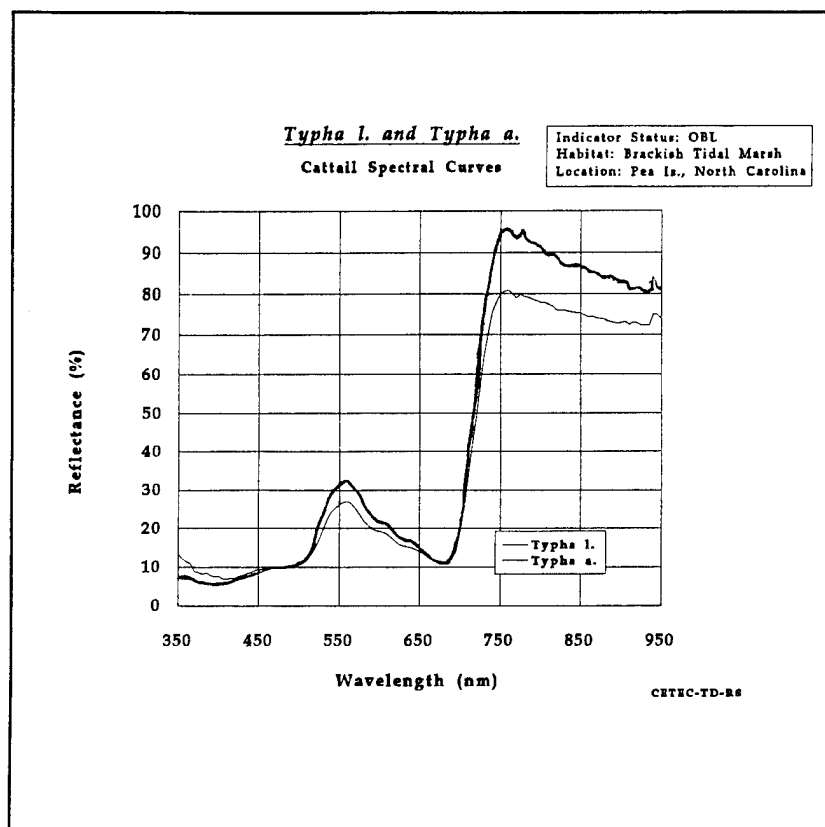
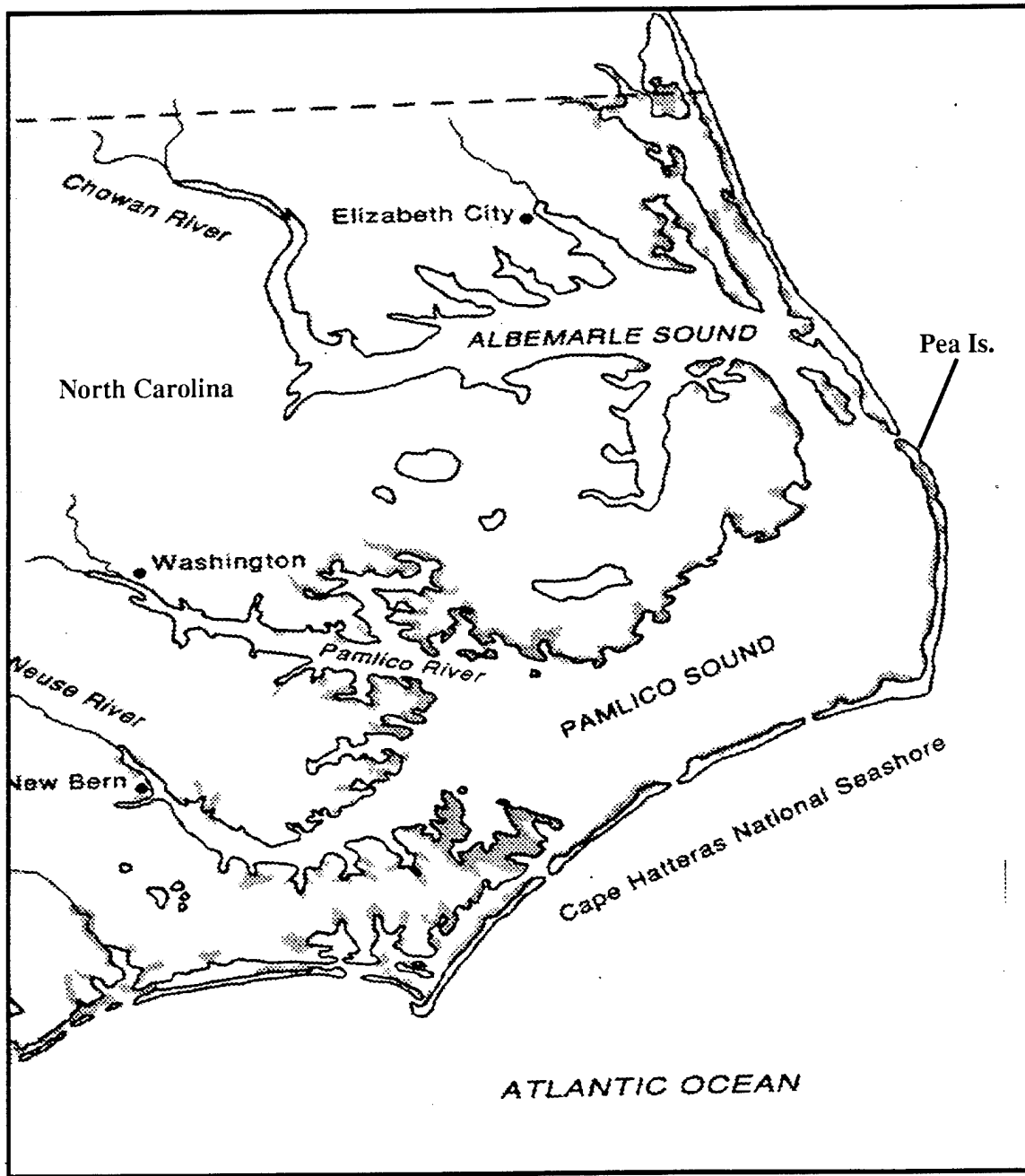


Figure 1 Spectra for two species of cattail.

using ASD software. Data reduction was accomplished using customized software (written in C) to reduce the data sets to a 5 nm bandpass. A cubic spline algorithm was used to smooth the data. All analysis and resulting graphics generation was accomplished using canned routines within Microsoft Excel and CA Cricket Graph.

Several areas were used representing coastal and non-tidal freshwater wetlands. Coastal plant specimens were sampled at Pea Island, North Carolina on the Outer Banks (Figure 2). All of the specimens from Pea Island occupy what is described as the high marsh region of the coastal wetland system. This is a zone described as irregularly flooded, where sea water mixes with freshwater run-off. The sampling area included a high marsh area near the Bodie Island lighthouse. This marsh had a broad diversity of plants, waterfowl, and wildlife.

Spectral reflectance measurements of plant canopies were collected *in-situ* using an Analytical Spectral Devices (ASD) PSII Spectroradiometer (350-950nm) with a 5 degree field-of-view. At 1 meter, this is equivalent to an 8 cm diameter sampling area. Three measurements were collected and averaged for each plant specimen. All samples were referenced to a Labsphere Spectralon reflectance standard. Measurements were collected as close to local solar noon as possible following the procedures of Satterwhite and Henley, (1991). Raw spectral files were downloaded from binary into ASCII formats

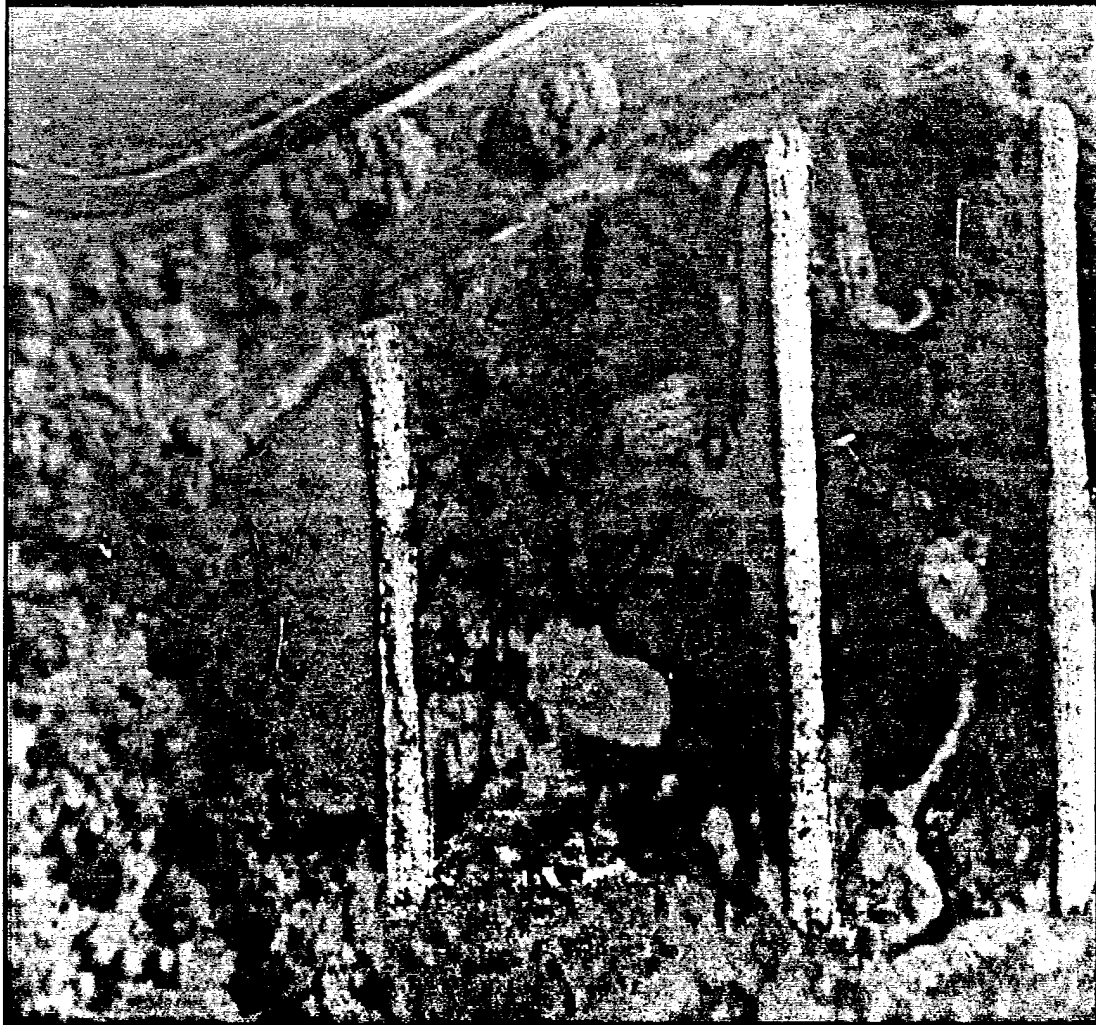


Map of coastal North Carolina showing Pea Island.

Spectral data for non-tidal freshwater plant specimens were measured at the Cedar Run wetlands mitigation site near Airlee, Virginia (Figure 3). The conditions at Cedar Run provide a unique opportunity to collect data on both disturbed and undisturbed wetland habitats due to the construction of dikes to create wetlands as part of a section 404 mitigation project. At the Cedar Run site, one can monitor the development of a man-made emergent marsh system as well as analyze the effects wetlands have on improving water quality. The Cedar Run site is a collection of earthen core and rock dikes that cross Cedar Run Creek. The dikes enable water to pass through a series of cells that contain a variety of soil substrates. Soil substrates vary from mineral fill material to organic peats containing plant propagules and seedbanks. The Soil Conservation Service and the Corps of Engineers have chosen to have different substrates to monitor wetland plant development in each of the cells. As water passes through the dikes, it enters the cells and provides the hydrologic gradient necessary for the development of hydric conditions in the soils. Once hydric conditions are established, hydrophytic vegetation is able to develop and colonize the cell areas.

CONCLUSION

Wetland plant spectra appears to vary greatly in chlorophyll and biomass reflectance as a function of plant species type and hydrologic regime (Anderson, 1995). Additionally, wetland plant reflectance has also been linked to changing soil redox potential, and can be indicative of nutrient stress (Anderson and Perry, 1995). The spectra recorded in this report provide a means to relate spectral signatures to imagery or multispectral scanner data which, depending on the sensor, record information in narrow or broad bands. This should be helpful in determining the zonation patterns of plants and the soil conditions associated with each plant type.



Cells at Cedar Run Wetland mitigation site.

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Appendix A. Wetland Plant Spectra

Field Reflectance Spectra of Vegetation

Plant Name: Beak Rush Date Collected: May 27, 1994
Scientific Name: *Eleocharus obtusa* (Willd.)
Spectrum No.W0009

Site Location: Cedar Run III, Airlie, Fauquier Co.,
Virginia, USA.
LAT. 38°41'deg. LONG. 77°46'deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

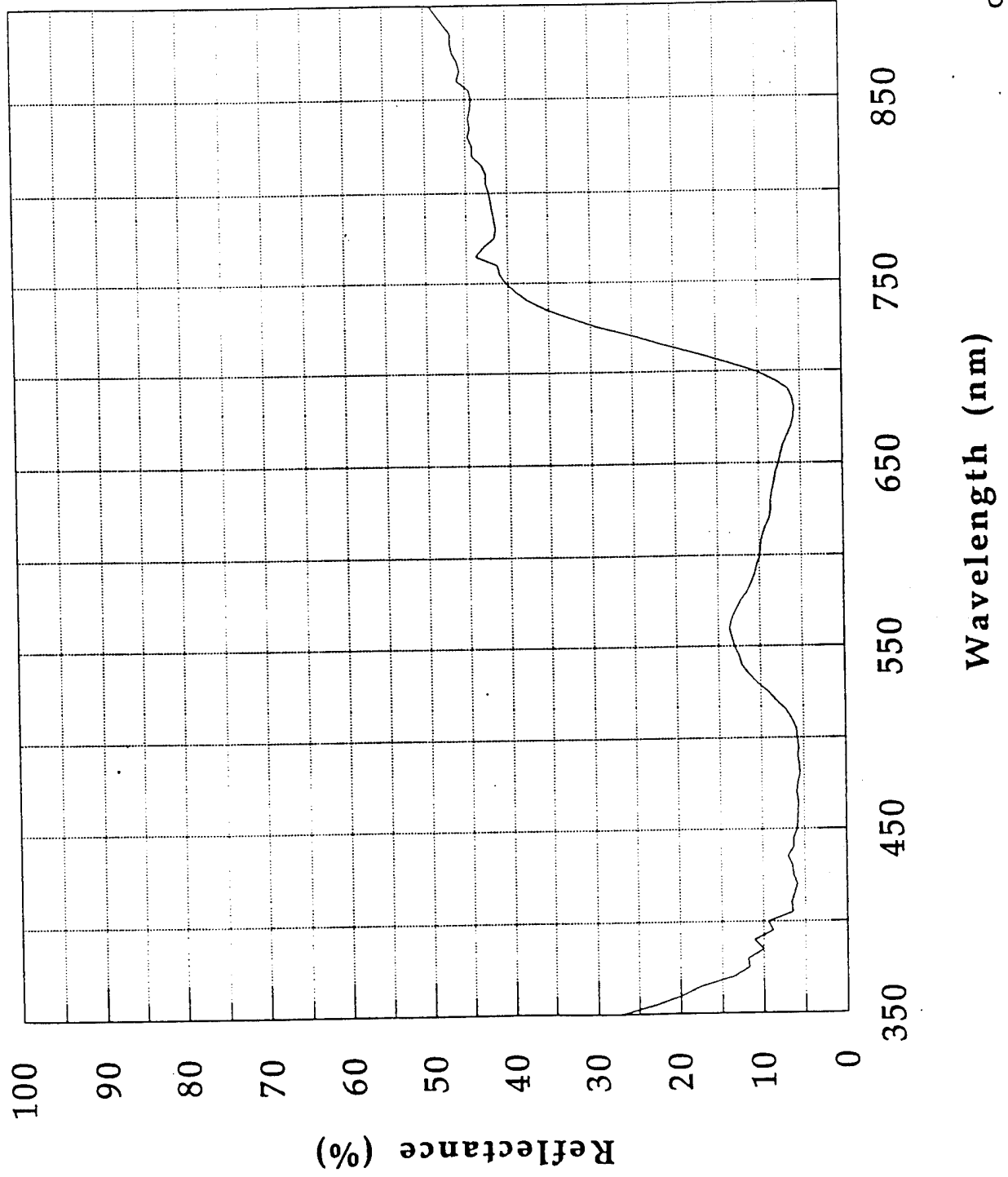
Sample: The *in-situ* leaf canopy was measured. A monotypic (cespitose) stand comprised of dense culms was used to obtain the characteristic reflectance. The specimens measured 15 cm tall with ovoid spikelets 3 mm long. Specimens were growing in disturbed soils. The soils were dark, wet, innundated mineral soils with an shallow organic A horizon. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative & flowering, turgid
Crown cover in the FOV: 90% Crown closure: 90%
Plant Height: 15 cm Crown diameter: 17 cm

Eleocharis obtusa

Indicator Status: OBL
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Field Reflectance Spectra of Vegetation

Plant Name: Spike (Salt) Grass Date Collected: May 27, 1994
Scientific Name: *Distichlis spicata* (L.)
Spectrum No. W0024

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprised of leaves was used to obtain the characteristic reflectance. The specimens sampled formed a medium to dense canopy of linear, erect leaves with hollow stems and light green leaves. The largest leaves measured 4.5 cm long and 3 to 4 mm wide. Specimens were growing in disturbed soils. The soils were dark, wet mineral soils. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

| | |
|--|----------------------|
| Phenological stage: vegetative, turgid | |
| Crown cover in the FOV: 100% | Crown closure: 50% |
| Plant Height: 10 cm | Crown diameter: 7 cm |

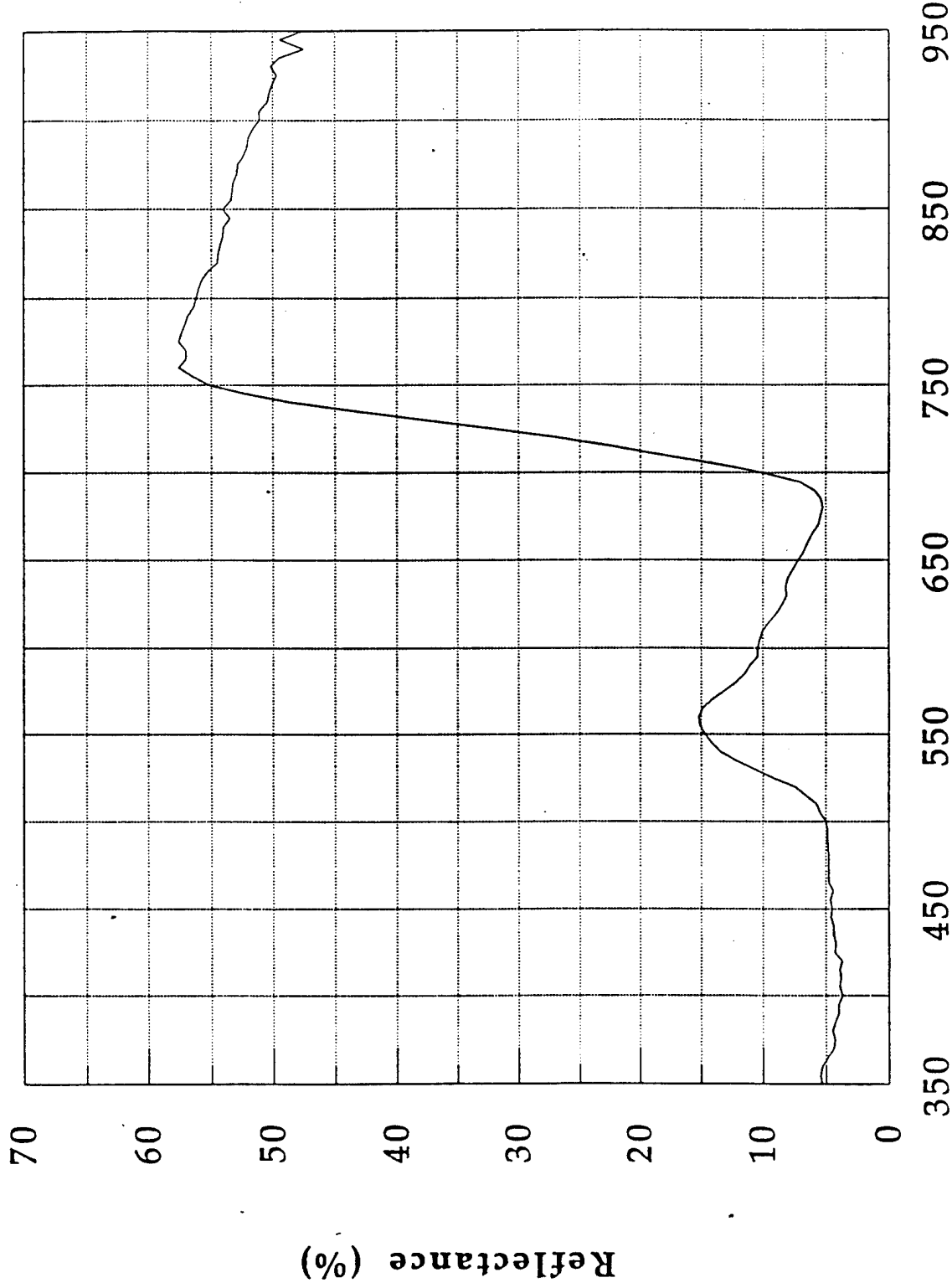
Distichlis spicata

"Salt Grass"

Indicator Status: FACW

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina



Wavelength (nm)

CETEC-TD-RS

Field Reflectance Spectra of Vegetation

Plant Name: Lurid Sedge Date Collected: May 27, 1994
Scientific Name: Carex lurida (Wahlenburg)
Spectrum No. W0011

Site Location: Cedar Run III, Airlie, Fauquier Co.,
Virginia, USA.
LAT. 38°41'deg. LONG. 77°46'deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprised of dense cespitose culms 6 dm tall was used to obtain the characteristic reflectance. Nutlets obovoid and tan- to straw-colored (2.5 cm long). Specimens were growing in disturbed soils. The soils were dark, wet, innundated mineral soils with an shallow organic A horizon. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

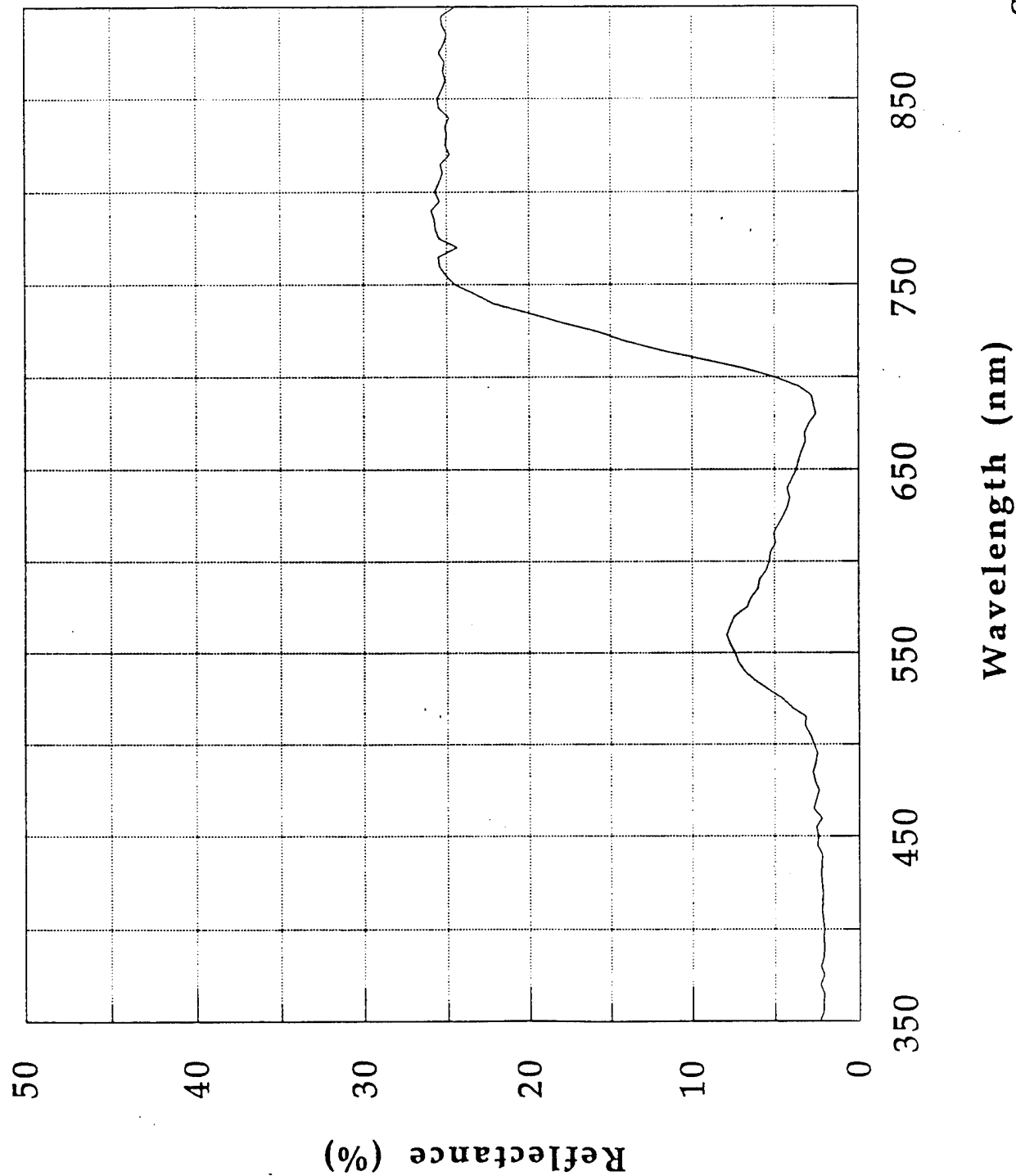
Physical & Chemical Properties:

Phenological stage: vegetative & fruiting, turgid
Crown cover in the FOV: 90% Crown closure: 75%
Plant Height: 6 dm Crown diameter: 20 cm

Carex lurida

Lurid Sedge

Indicator Status: OBL
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Field Reflectance Spectra of Vegetation

Plant Name: _____ Date Collected: May 27, 1994
Scientific Name: Carex annectens (Bicknell)
Spectrum No. W0012

Site Location: Cedar Run III, Airlie, Fauquier Co.,
Virginia, USA.
LAT. 38°41'deg. LONG. 77°46'deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprised of dense, culms 5 to 7 dm tall was used to obtain the characteristic reflectance. Nutlets were tan colored (1.5 cm long). Specimens were growing in disturbed soils. The soils were dark, wet, innundated mineral soils with an shallow organic A horizon. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

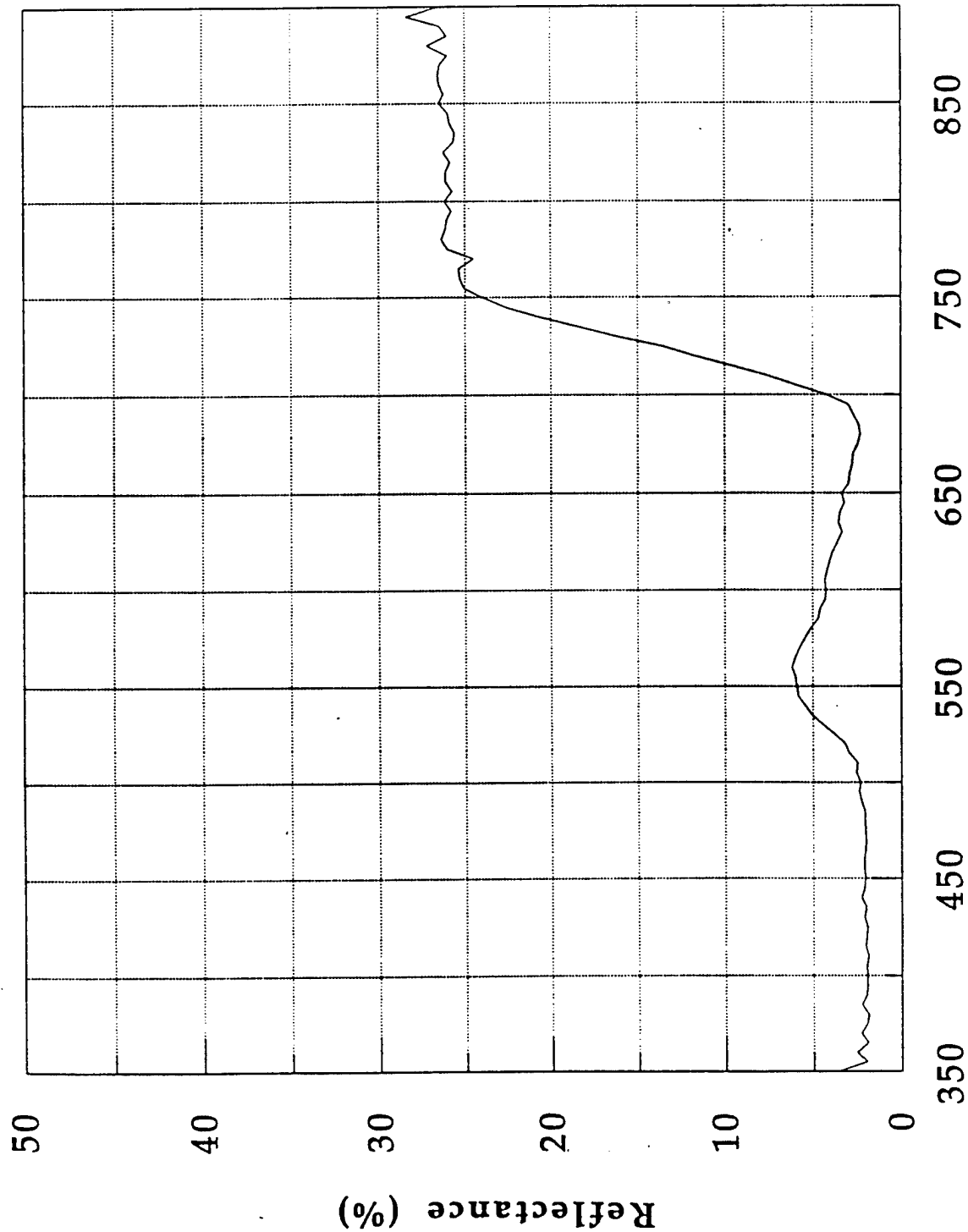
Phenological stage: vegetative & fruiting, turgid
Crown cover in the FOV: 75% Crown closure: 70%
Plant Height: 6 dm (average) Crown diameter: 25 cm

Carex annectens

Indicator Status: OBL

Habitat: Fresh Emergent Marsh

Cedar Run (3), Airlee, Virginia



Wavelength (nm)

Field Reflectance Spectra of Vegetation

Plant Name: Boneset Date Collected: May 27, 1994
Scientific Name: Eupatorium perfoliatum (L.)
Spectrum No.W0013

Site Location: Cedar Run III, Airlie, Fauquier Co.,
 Virginia, USA.
 LAT. 38°41'deg. LONG. 77°46'deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5- degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprised of leaves was used to obtain the characteristic reflectance. The specimens sampled formed a loose canopy of pubescent, serrated, triangular-shaped, simple green leaves. The largest leaves measured 5 cm long and 2.5 cm wide. Specimens were growing in disturbed soils. The soils were dark, wet mineral soils. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 100%
Plant Height: 1 m

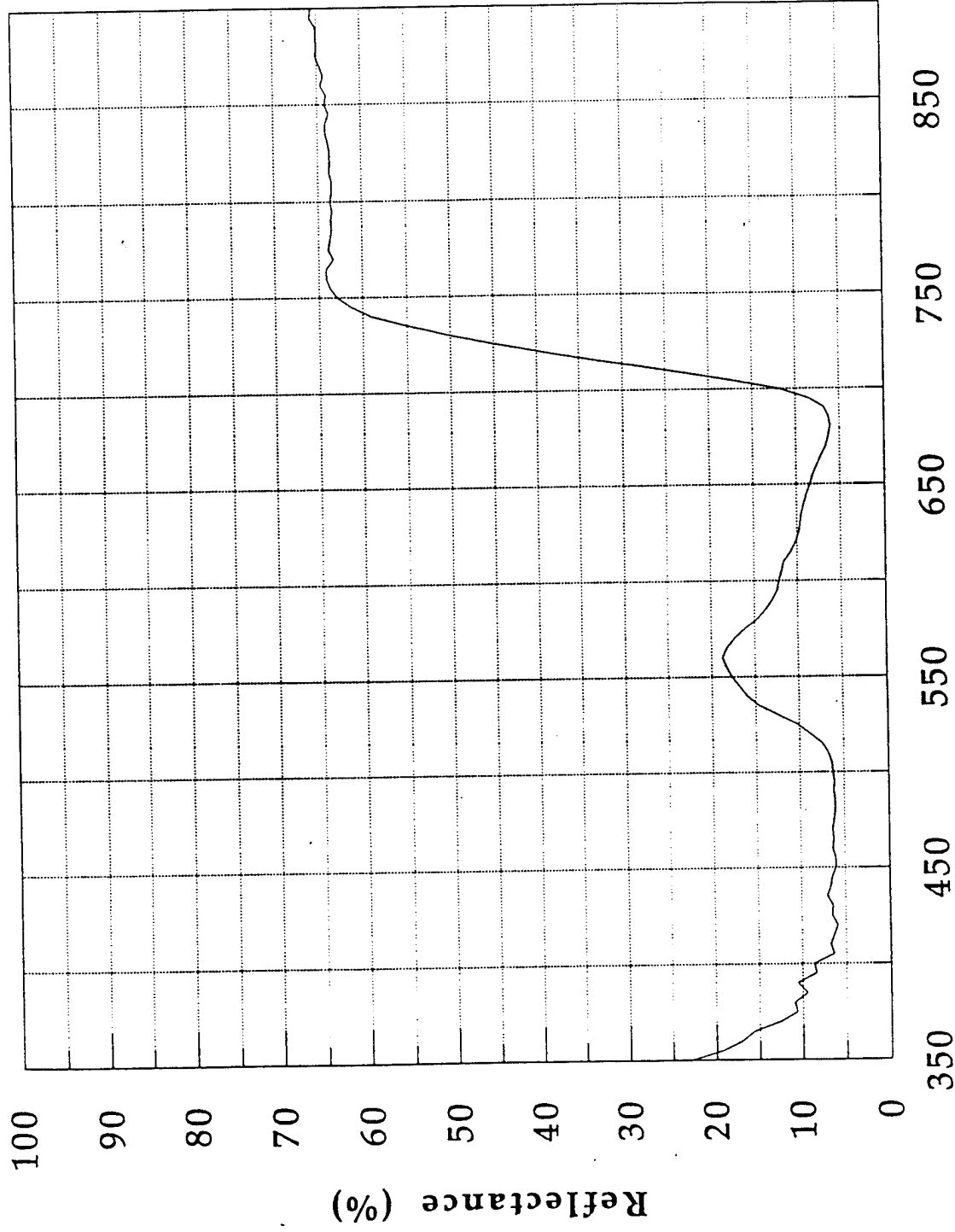
Crown closure: 50%
Crown diameter: 12

cm

Eupatorium perfoliatum

Boneset

Indicator Status: FACW
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Wavelength (nm)

Field Reflectance Spectra of Vegetation

Plant Name: False willow Date Collected: May 27, 1994
Scientific Name: *Baccharis angustifolia* (L.)
Spectrum No. W0026

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
 sampled North Carolina, USA.
 LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* shrub canopy was measured. A monotypic stand comprised of leaves and stems was used to obtain the characteristic reflectance. The sampled specimens were tall and erect with dark green, narrow, egg-shaped leaves 1.5cm long. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 75% Crown closure: 60%
Plant Height: 1.5m Crown diameter: <.25m

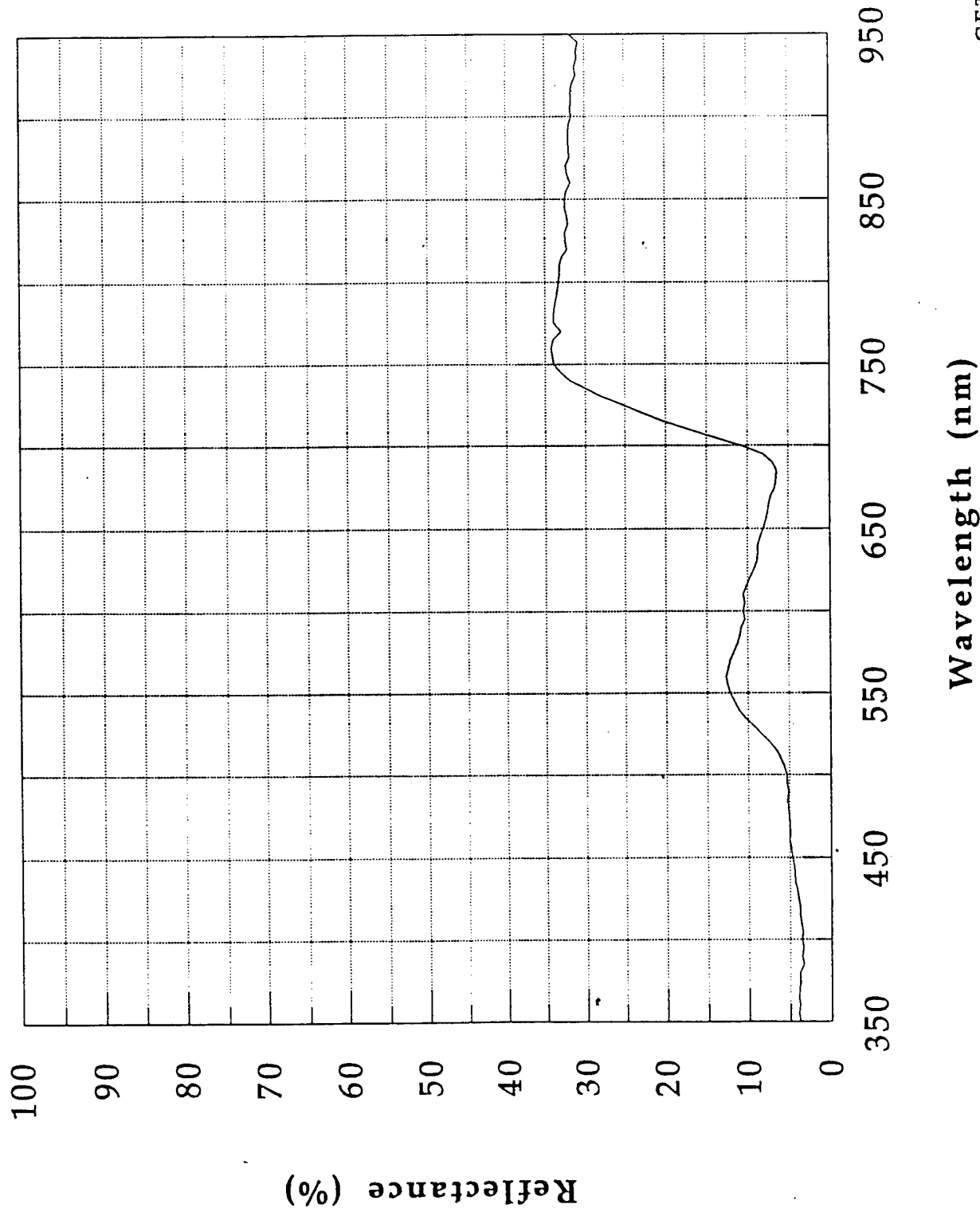
Baccharis angustifolia

"False Willow"

Indicator Status: FACW

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina



Field Reflectance Spectra of Vegetation

Plant Name: Smooth Alder Date Collected: May 27, 1994
Scientific Name: *Alnus serrulata* (L.)
Spectrum No. W0014

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* shrub leaves were measured. A leaf mosaic was made from five excised leaves obtained from different parts of the canopy. Leaves measured 10.5 cm long by 7.8 cm wide. The specimens sampled were tall (<10m), broad-leaved deciduous shrubs with bright green, serrated, oval leaves. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

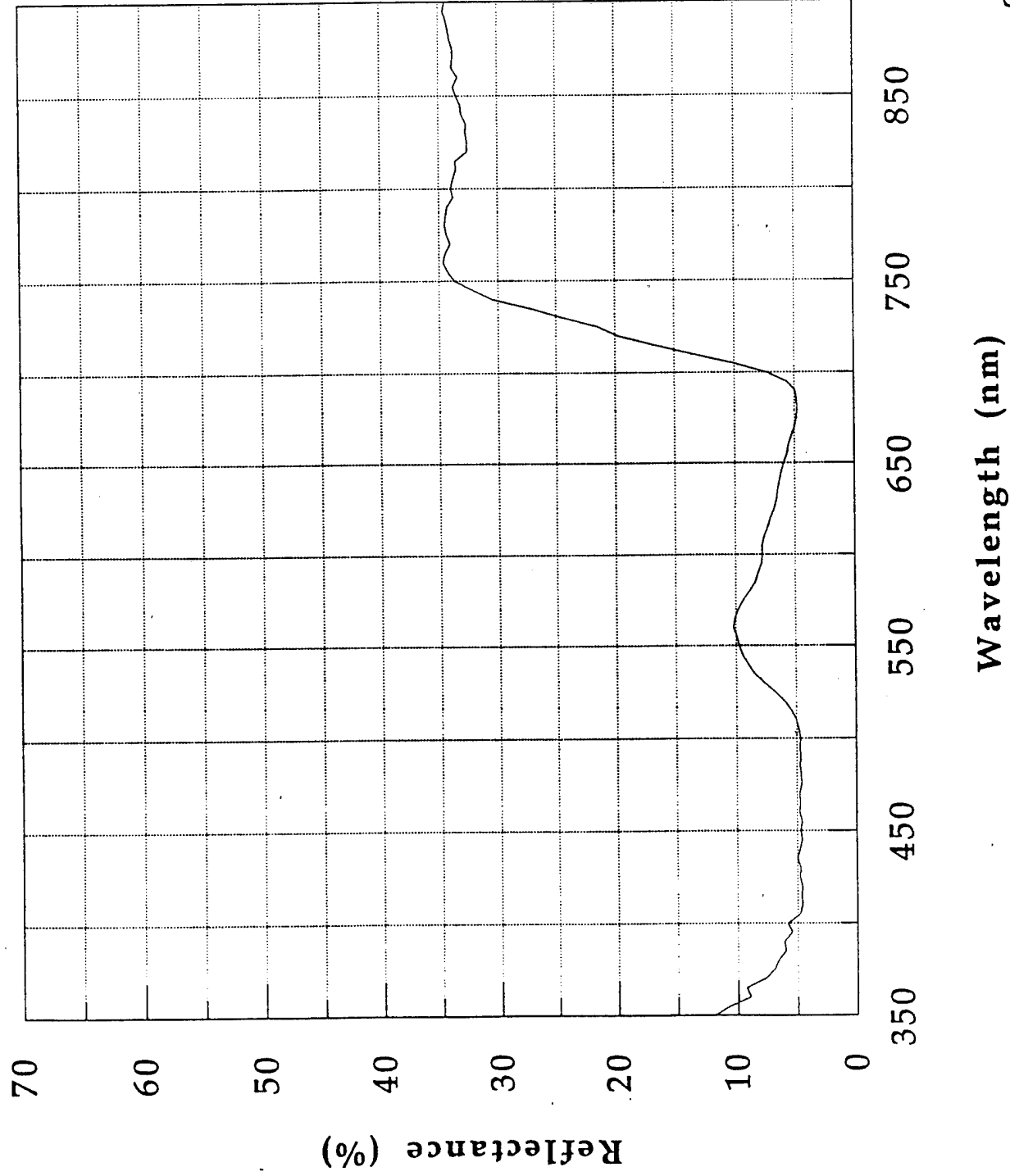
Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 100% Crown closure: 60%
Plant Height: <10m Crown diameter: <3m

Alnus serrulata

Tag Alder

Indicator Status: FACW
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Field Reflectance Spectra of Vegetation

Plant Name: Three Square (Sedge) Date Collected: May 27, 1994
Scientific Name: Scirpus pungens (Vahl)
Spectrum No. W0015

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* sedge canopy was measured. Monotypic canopies comprised of both leaves and stems were used to obtain the characteristic reflectance. The specimen sampled was an erect, perennial herb with triangular stems in combination with several stem-like leaves. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

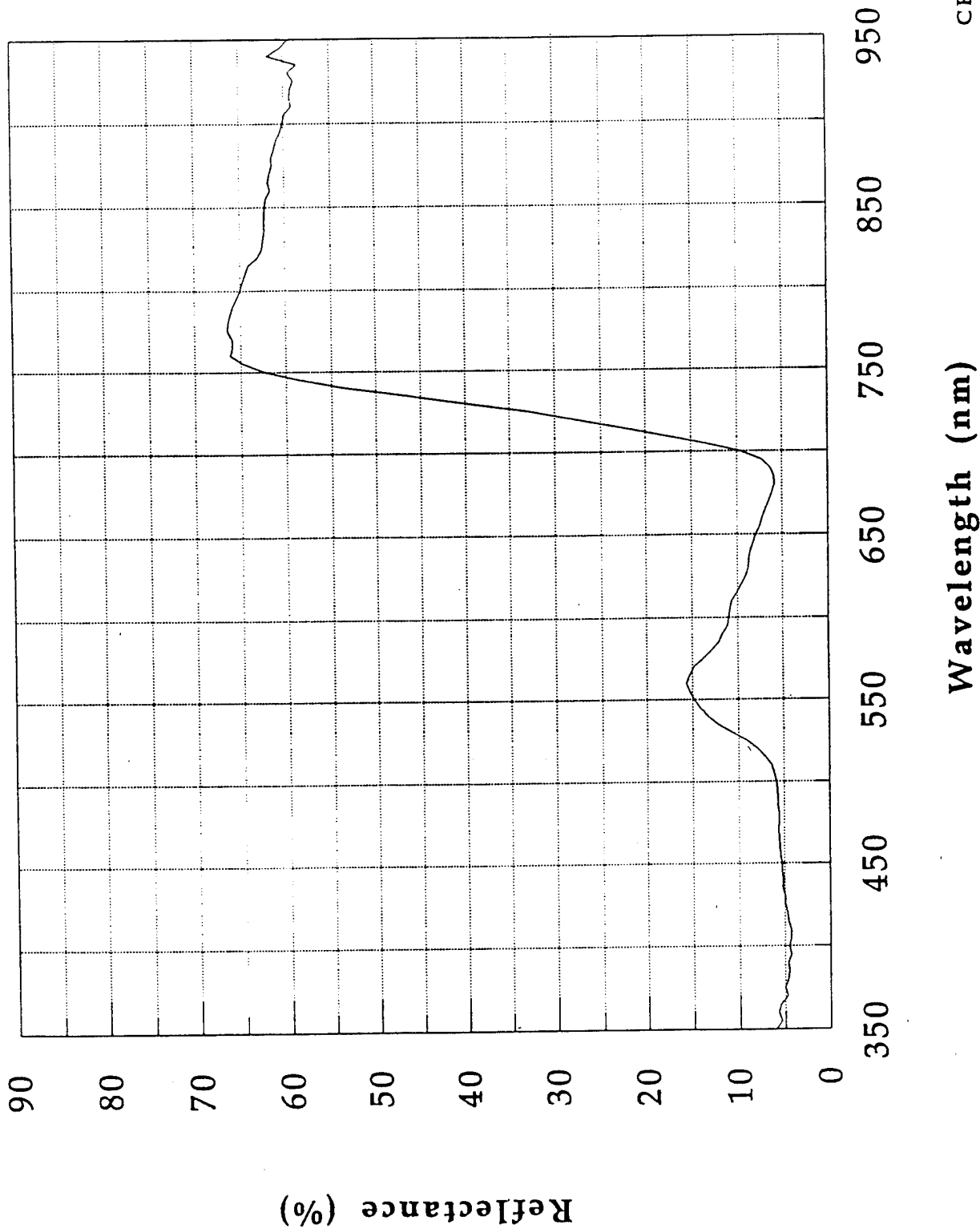
Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 100% Crown closure: 70%
Plant Height: .5m Crown diameter: 0.25m

Scirpus pungens

"Common Three-square"

Indicator status: FACW
Habitat: Brackish Tidal Marsh
Location: Pea Is., North Carolina



Field Reflectance Spectra of Vegetation

Plant Name: _____ Date Collected: May 27, 1994
Scientific Name: Juncus acuminatus (Michaux)
Spectrum No. W0010

Site Location: Cedar Run III, Airlie, Fauquier Co.,
Virginia, USA.
LAT. 38°41'deg. LONG. 77°46'deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

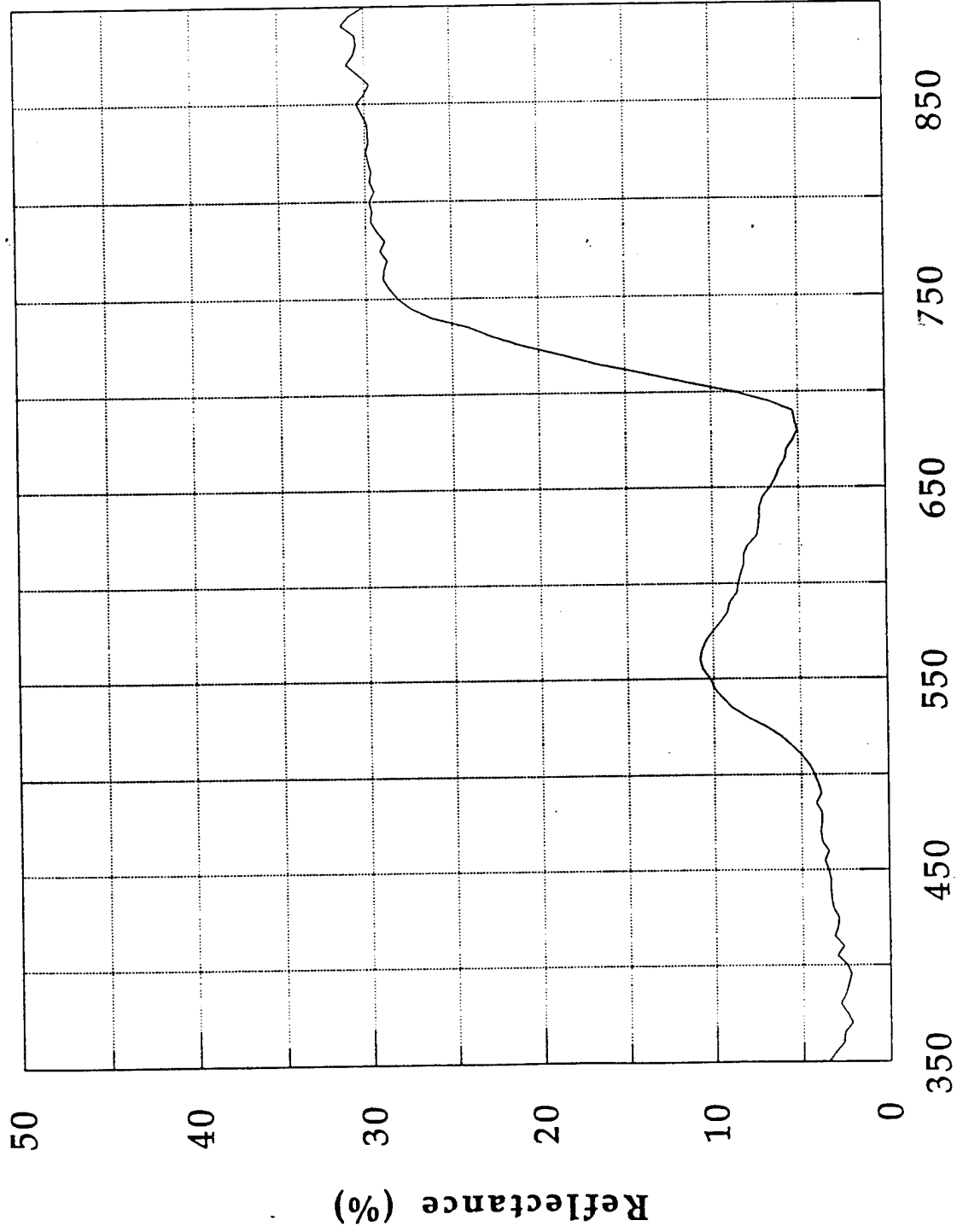
Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprised of dense tufts was used to obtain the characteristic reflectance. The specimens measured 5 dm tall with septate and slender leaves with flowering inflorescence, light brown to tan. Specimens were growing in disturbed soils. The soils were dark, wet, innundated mineral soils with an shallow organic A horizon. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

| | |
|--|-----------------------|
| Phenological stage: vegetative & flowering, turgid | |
| Crown cover in the FOV: 75% | Crown closure: 90% |
| Plant Height: 5 dm | Crown diameter: 15 cm |

Juncus acuminatus

Indicator Status: FACW
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Wavelength (nm)

CETEC-TD-RS

Field Reflectance Spectra of Vegetation

Plant Name: Soft rush
Scientific Name: Juncus effusus (L.)
Spectrum No. W0008

Date Collected: May 27, 1994

Site Location: Cedar Run III, Airlie, Fauquier Co.,
Virginia, USA.
LAT. 38°41'deg. LONG. 77°46'deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprised of dense, tufted scapes was used to obtain the characteristic reflectance. The specimens sampled formed a dense stand of dark green scapes with a brown flowering inflorescence. The specimens measured 1 m tall. Specimens were growing in disturbed soils. The soils were dark, wet, innundated mineral soils with an shallow organic A horizon. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

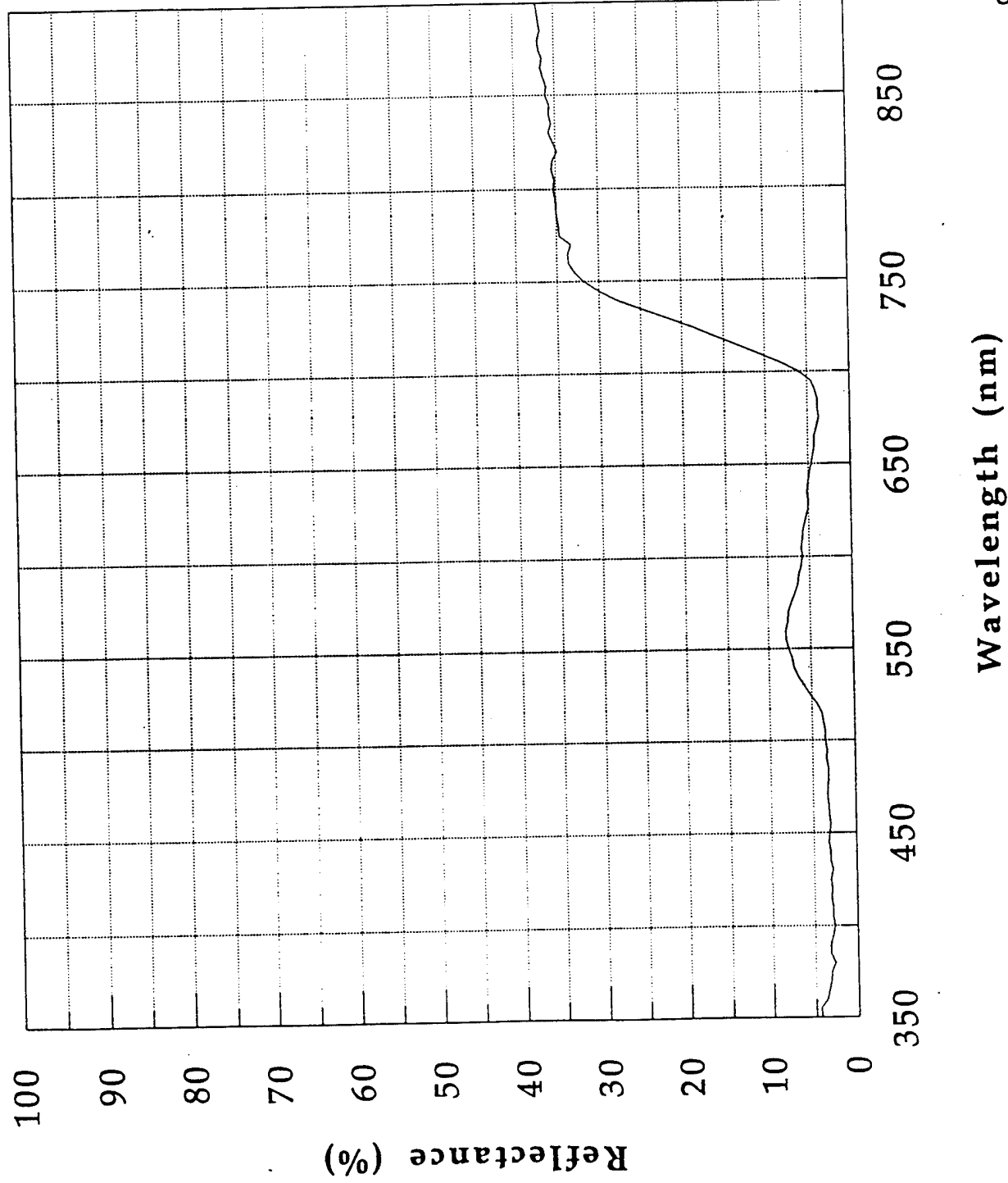
Physical & Chemical Properties:

| | |
|--|----------------------|
| Phenological stage: vegetative & flowering, turgid | |
| Crown cover in the FOV: 90% | Crown closure: 90% |
| Plant Height: 1 m | Crown diameter: .5 m |

Juncus effusus

Soft Rush

Indicator Status: FACW
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Field Reflectance Spectra of Vegetation

Plant Name: Black Needle Rush Date Collected: May 27, 1994
Scientific Name: *Juncus roemarianus* (L.)
Spectrum No. W0022

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned so fill the radiometer field-of-view.

Sample: The *in-situ* rush canopy was measured. A monotypic stand comprised of leaves and stems was used to obtain the characteristic reflectance. The sampled specimens were tall and erect with sharp pointed leaves which varied in color from dark greenish-gray to olive. Leaves were round in cross-section and measured 1.5 m or more. Some gray-colored dead stems were present in the specimens. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 95% Crown closure: 90%
Plant Height: 2m Crown diameter: 1.5m

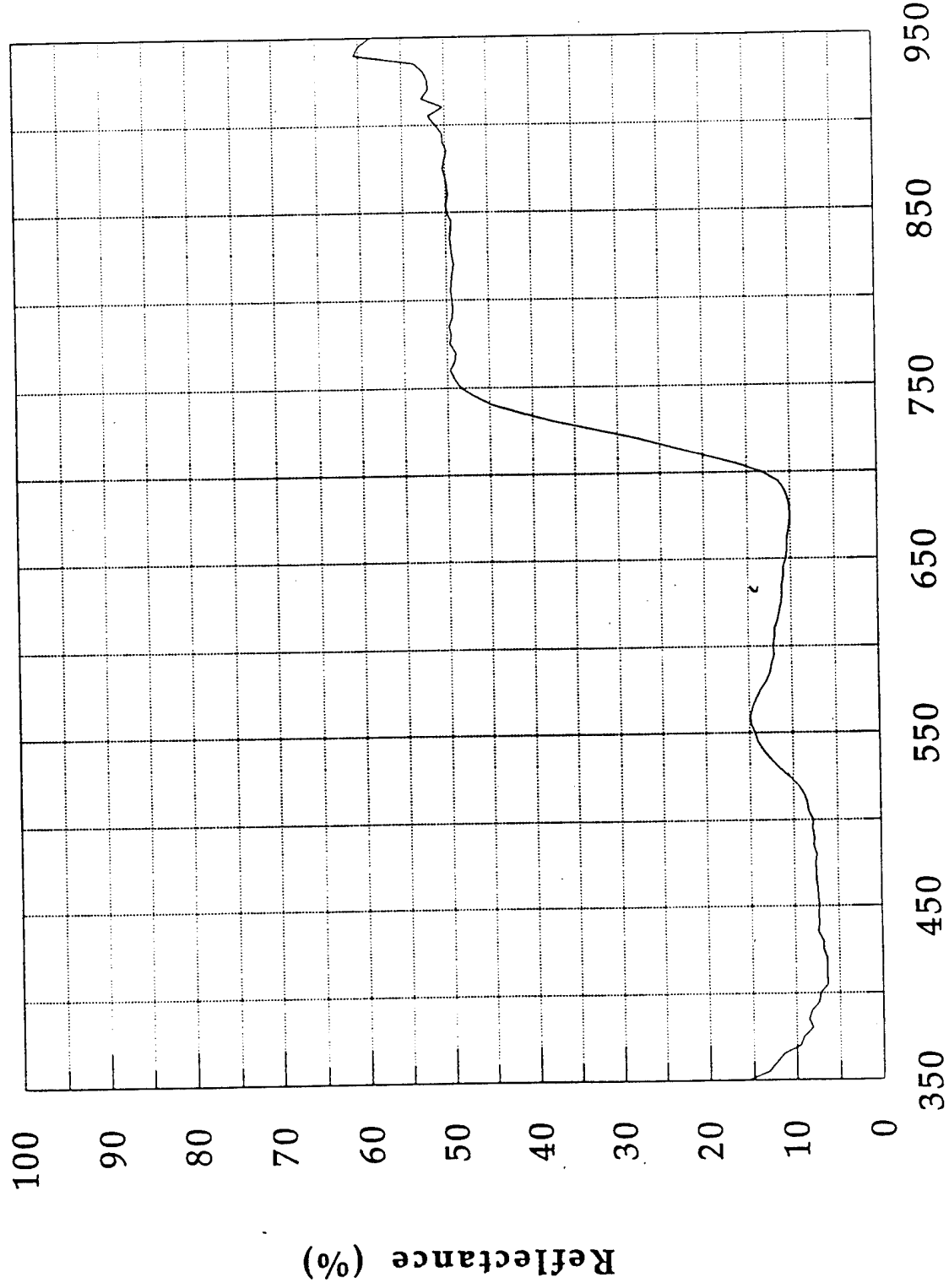
Juncus roemerianus

"Black Rush"

Indicator Status: OBL

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina



Wavelength (nm)

CETEC-TD-RS

Field Reflectance Spectra of Vegetation

Plant Name: Rice Cutgrass Date Collected: May 27, 1994
Scientific Name: Leersia oryzoides (L.)
Spectrum No. W0007

Site Location: Cedar Run III, Airlie, Fauquier Co.,
 Virginia, USA.
 LAT. 38°41'deg. LONG. 77°46'deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprised of culms and leaf blades was used to obtain the characteristic reflectance. The specimens sampled formed a loose stand of green leaves. The culms measured 6 dm tall and the largest leaves (blades) measured 1 dm long and 3 mm wide. Specimens were growing in disturbed soils and wet fill material. The soils were light, wet, innundated mineral soils. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

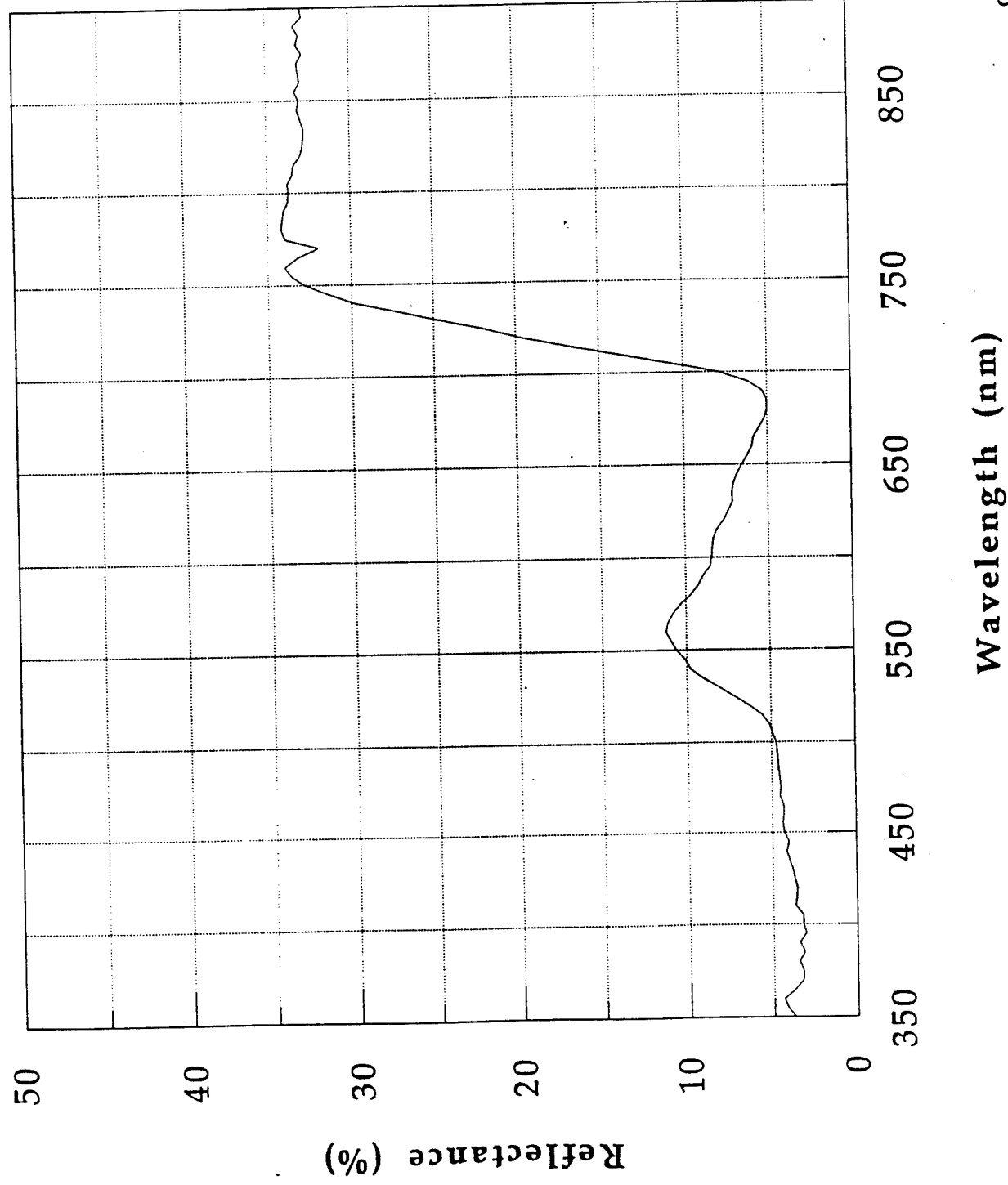
Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 60% Crown closure: 70%
Plant Height: 5-6 dm Crown diameter: 1 m

Leersia oryzoides

Rice Cutgrass

Indicator Status: OBL
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Field Reflectance Spectra of Vegetation

Plant Name: Mint or Bugleweed Date Collected: May 27, 1994
Scientific Name: Lycopus virginicus (Willd.)
Spectrum No. W0006

Site Location: Cedar Run III, Airlie, Fauquier Co.,
Virginia, USA.
LAT. 38°41'deg. LONG. 77°46'deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprised of leaves was used to obtain the characteristic reflectance. The specimens sampled formed an dense canopy of acuminate, serrate green leaves. The largest leaves measured 4 cm long and 3 cm wide. Specimens were growing in disturbed soils. The soils were dark, wet, innundated mineral soils. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

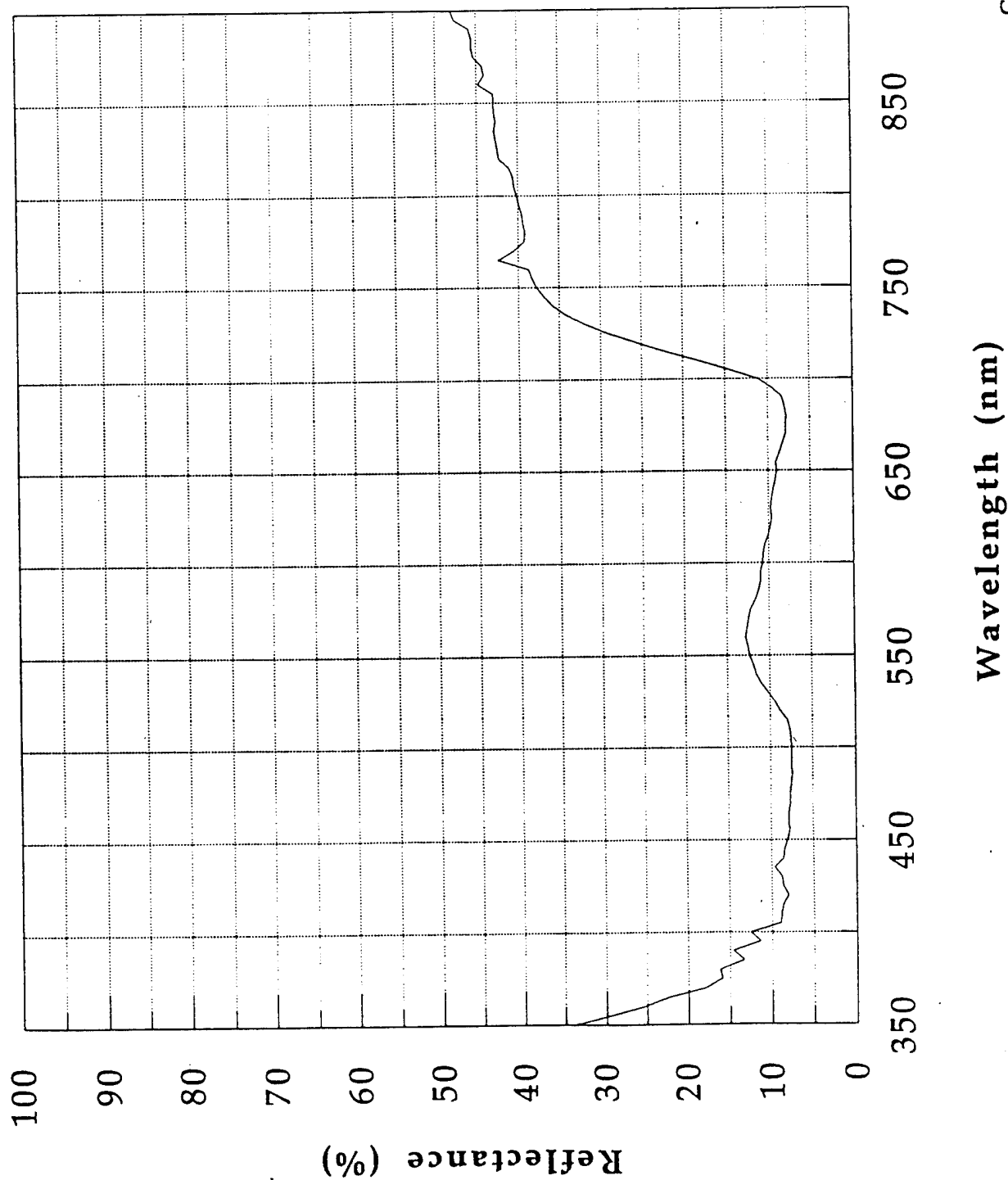
Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 100% Crown closure: 90%
Plant Height: 35 cm Crown diameter: 25 cm

Lycopus virginicus

Bugleweed (mint)

Indicator Status: OBL
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Field Reflectance Spectra of Vegetation

Plant Name: Marsh Mallow Date Collected: May 27, 1994
Scientific Name: Hibiscus moscheutos (L.)
Spectrum No. W0021

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned so fill the radiometer field-of-view.

Sample: The *in-situ* herb canopy was measured. A monotypic stand comprised of leaves and stems was used to obtain the characteristic reflectance. The sampled specimens were tall, erect, perennial herbs. The leaves that were measured were bright green, simple and lobed. Some leaves were exposing pubescent undersides. Specimens were flowering at the time collections were made. Flowers were not included in the spectral sample. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 100% Crown closure: 80%
Plant Height: 1m Crown diameter: <.25m

Compiled by: J.E. Anderson, CETEC-TD-RS

Sheet No.: VM-W001

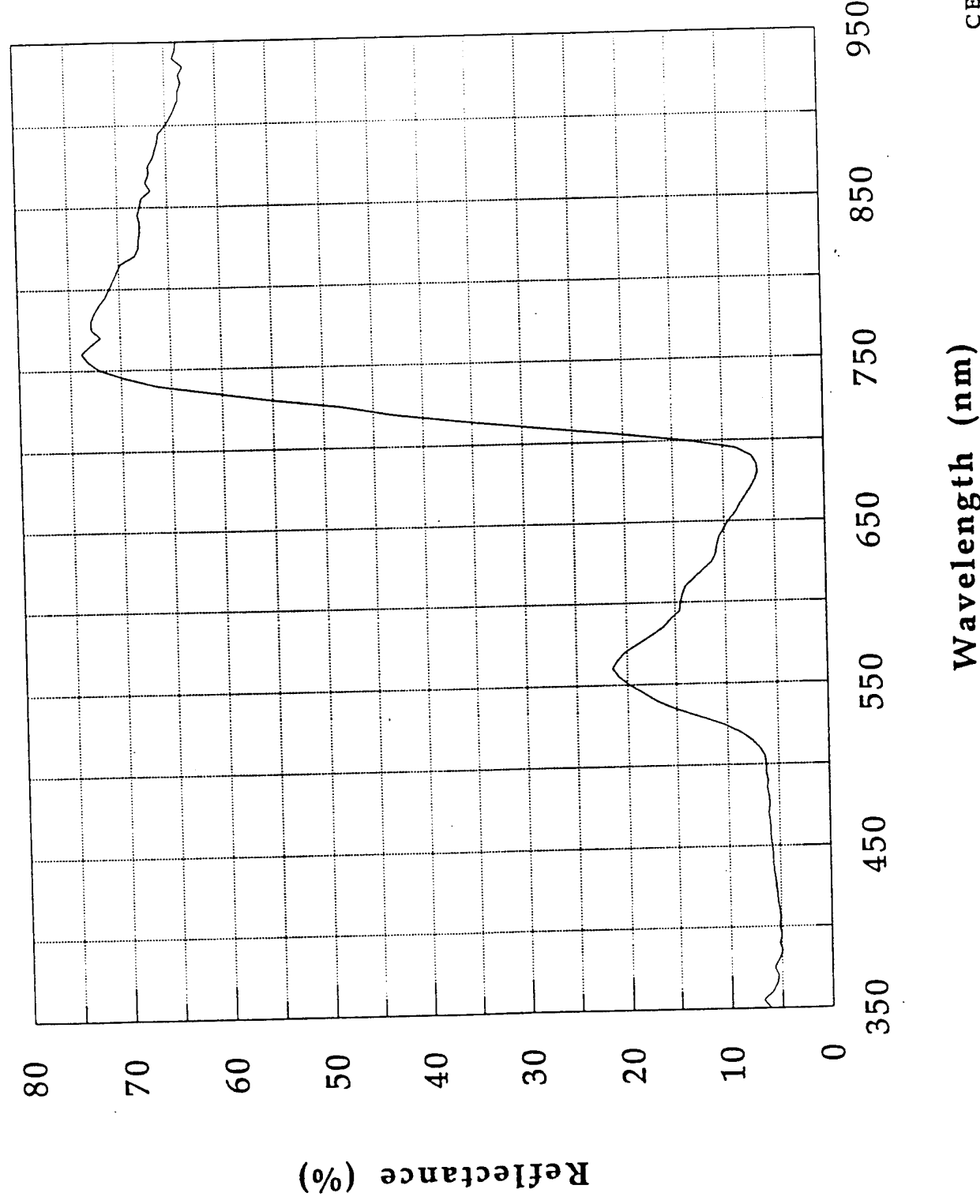
Hibiscus moscheutos

"Marsh Mallow"

Indicator Status: OBL

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina



Field Reflectance Spectra of Vegetation

Plant Name: Wax Myrtle Date Collected: May 27, 1994
Scientific Name: Myrica cerifera (L.)
Spectrum No. W0018

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned so fill the radiometer field-of-view.

Sample: The *in-situ* shrub canopy was measured. A monotypic stand comprised of both evergreen leaves and stems was used to obtain the characteristic reflectance. The specimen sampled was an evergreen shrub with oblong, yellow-green, shiny leaves. The largest leaves measured 2.3 cm wide and 4 cm long. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 90% Crown closure: 70%
Plant Height: <2m Crown diameter: >1m

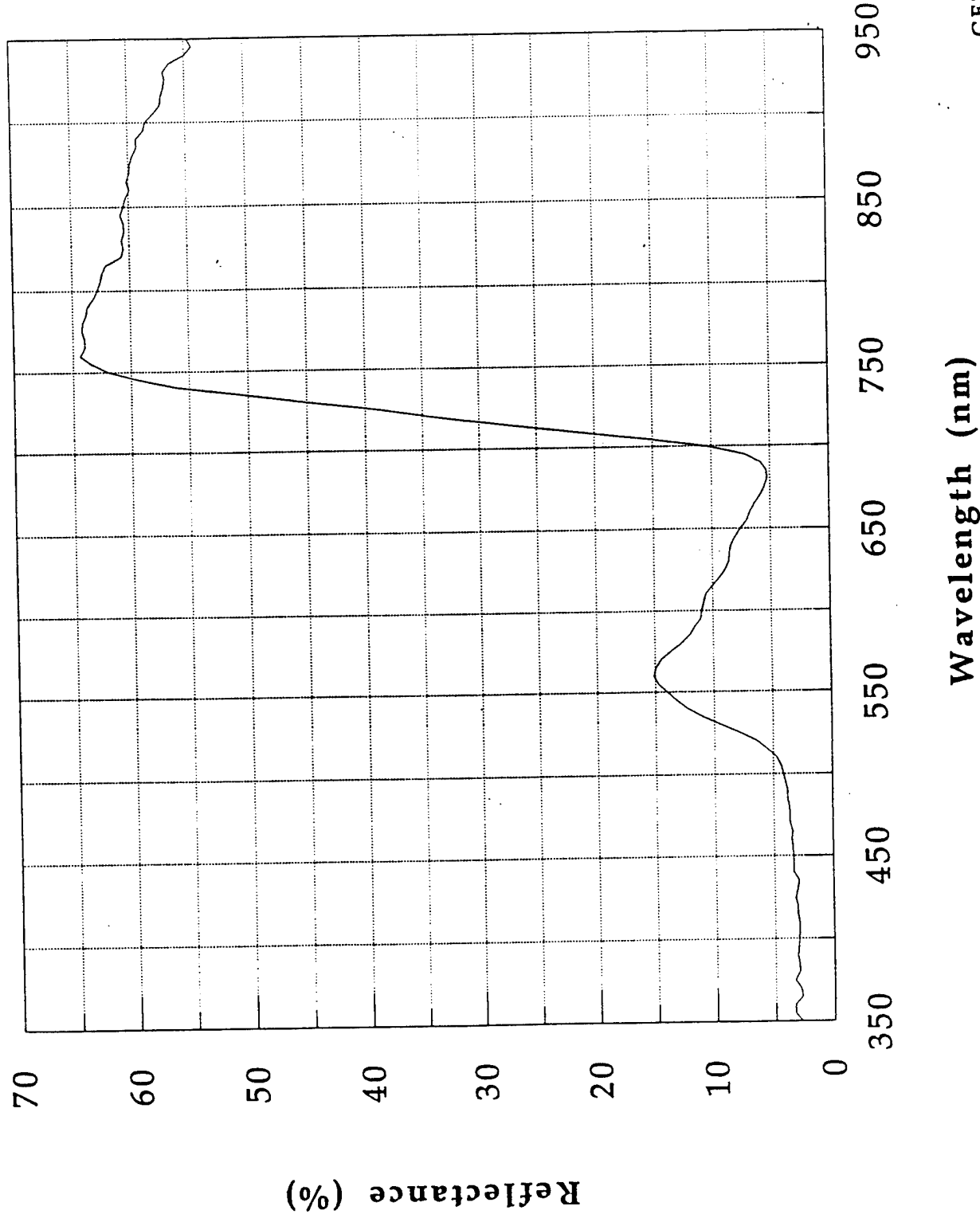
Myrica cerifera

"Wax Myrtle"

Indicator Status: FAC

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina



Field Reflectance Spectra of Vegetation

Plant Name: Bayberry Date Collected: May 27, 1994
Scientific Name: *Myrica pennsylvanica* (L.)
Spectrum No. W0025

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* shrub canopy was measured. A monotypic stand comprised of evergreen leaves was used to obtain the characteristic reflectance. The sampled specimen was an evergreen shrub with oblong, dark green, shiny leaves, a species similar to *Myrica cerifera*. The largest leaves measured 2 cm wide and 4 cm long. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

| | |
|--|----------------------|
| Phenological stage: vegetative, turgid | |
| Crown cover in the FOV: 85% | Crown closure: 80% |
| Plant Height: 2m | Crown diameter: 2.5m |

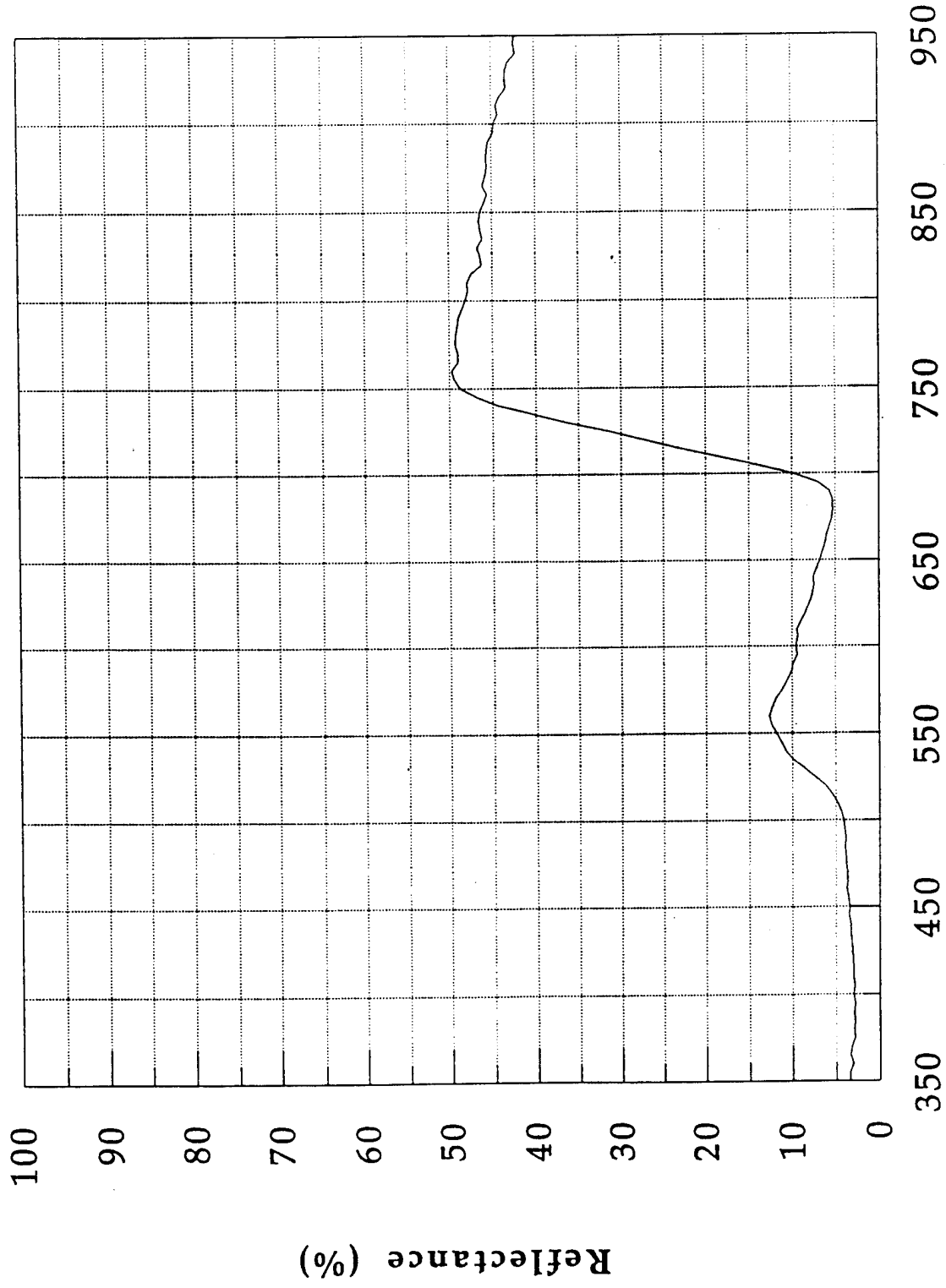
Myrica pennsylvanica

"Bayberry"

Indicator Status: FAC

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina



Wavelength (nm)

Field Reflectance Spectra of Vegetation

Plant Name: Water Plantain Date Collected: June 28, 1994
Scientific Name: *Alisma plantago-aquatica* (L.)
Spectrum No. W0002

Site Location: Cedar Run III Wetland Mitigation Site, Airlee,
(Warrenton), Virginia, USA.
LAT. 38°41' deg. LONG. 77°46' deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5 degree (.0872rad) FOV. Spectral samples taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: *In-situ* spectral reflectance of the specimen was collected. Sample was a rooted aquatic perennial herb. Leaf canopy was moderately dense with simple, egg-shaped leaves measuring 14 cm long and 6 cm wide. Specimen was rooted in flooded red mineral soil of Cell 5.

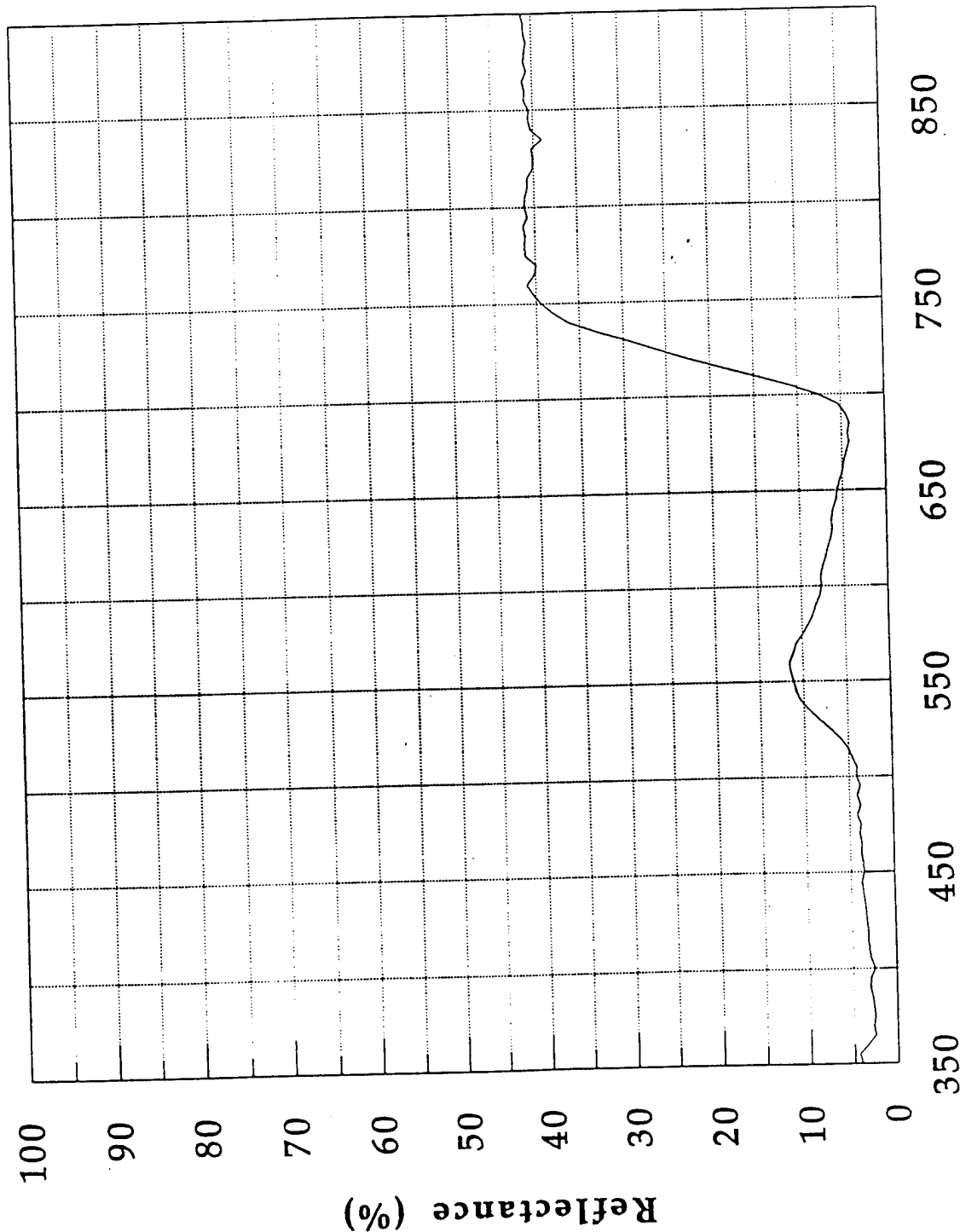
Physical & Chemical Properties:

Phenological stage: vegetative, flaccid
Crown cover in the FOV: 90% Crown closure: 65%
Plant Height: 18cm Crown diameter: 10cm

Alisma plantago-aquatica

N. Water Plantain

Indicator Status: OBL
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Wavelength (nm)

CETEC-TD-RS

Field Reflectance Spectra of Vegetation

Plant Name: Common Reed Date Collected: May 27, 1994
Scientific Name: Phragmites communis (L.)
Spectrum No. W0020

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned so fill the radiometer field-of-view.

Sample: The *in-situ* grass canopy was measured. A monotypic stand comprised of leaves and stems was used to obtain the characteristic reflectance. The specimens sampled were tall, erect, dense green leaves. The largest leaves measured 0.5 m long and 1.5 cm wide. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 75% Crown closure: 80%
Plant Height: 2m Crown diameter: <.5m

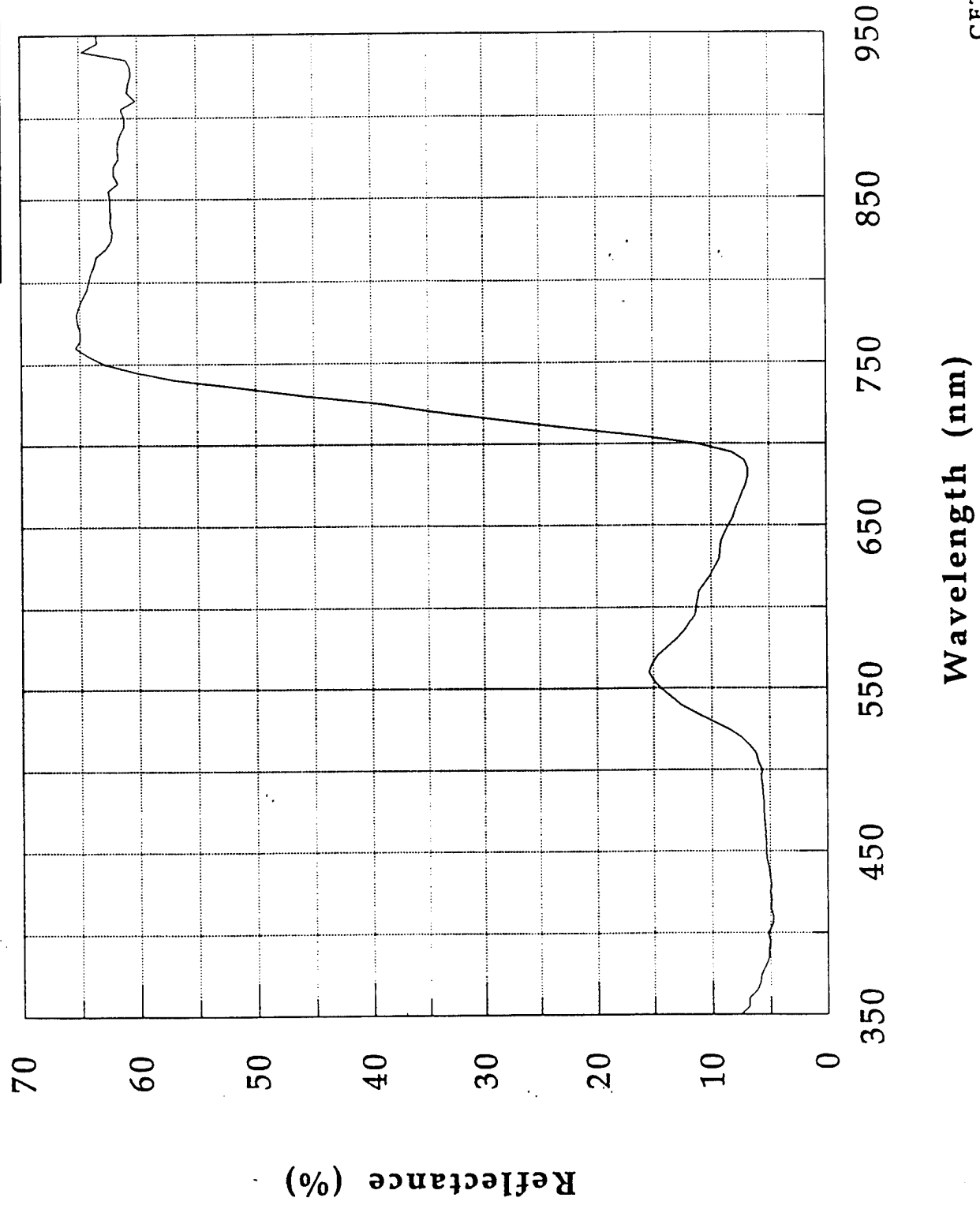
Phragmites communis

"Common Reed"

Indicator Status: FACW

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina



Field Reflectance Spectra of Vegetation

Plant Name: Pondweed Date Collected: May 27, 1994
Scientific Name: Potamogeton diversifolius (Raf.)
Spectrum No. W0001

Site Location: Cedar Run III, Airlie, Fauquier Co.,
Virginia, USA.
LAT. 38° 41' deg. LONG. 77° 46' deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5 degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* floating leaf canopy was measured. A monotypic stand comprised of leaves was used to obtain the characteristic reflectance. The specimens sampled formed a dense mat of elliptic, dense green leaves. The largest leaves measured 2.5 cm long and 7 mm wide. Specimens were growing in disturbed soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 75% Crown closure: 80%
Plant Height: floating aquatic Crown diameter: <.5m

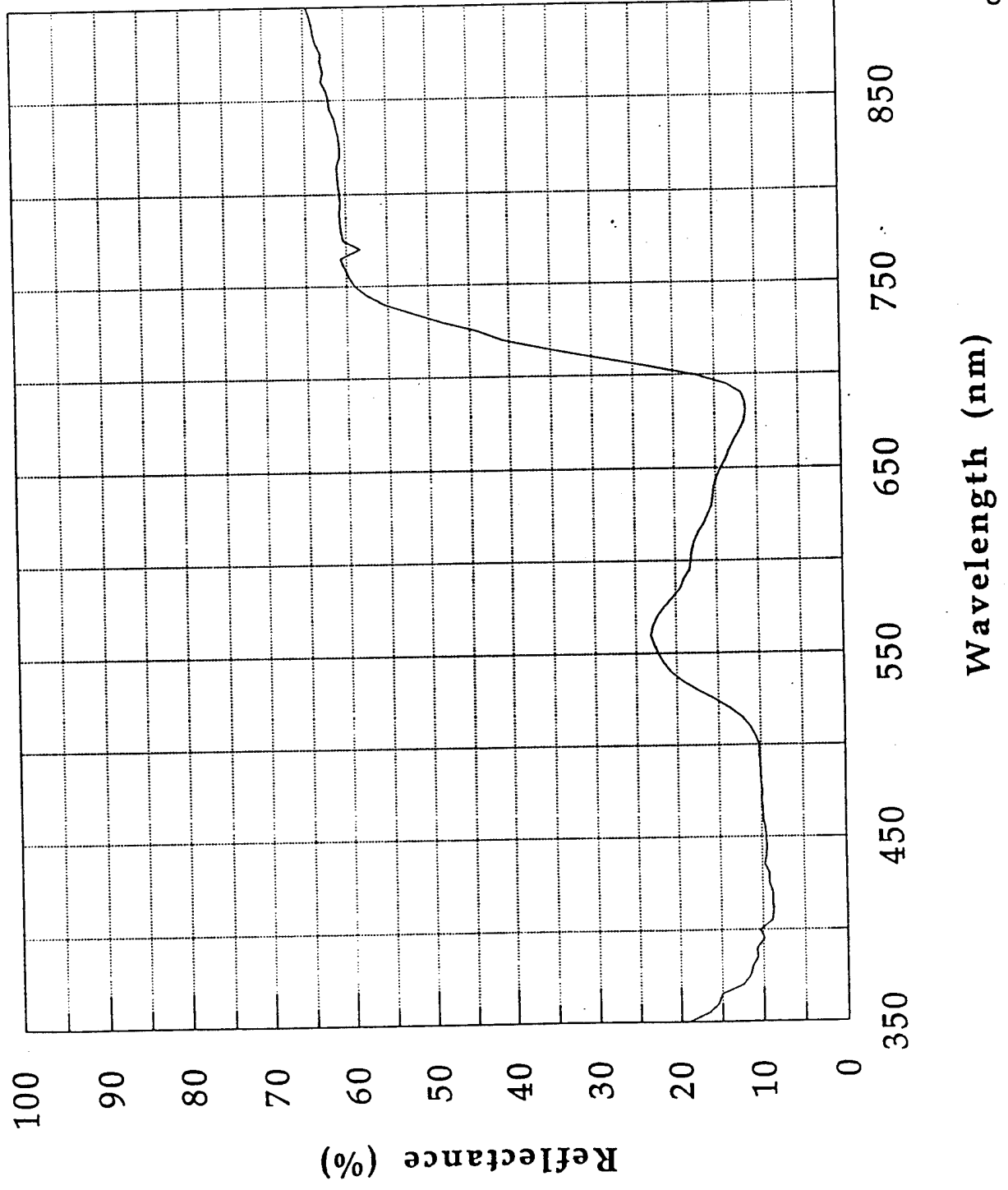
Compiled by: J.E. Anderson, CETEC-TD-RS

Sheet No.:VP-W001

Potamogeton diversifolius

Pondweed

Indicator Status: OBL
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Field Reflectance Spectra of Vegetation

Plant Name: Sycamore Date Collected: May 27, 1994
Scientific Name: Plantanus occidentalis (L.)
Spectrum No.

Site Location: Cedar Run III, Airlie, Fauquier Co.,
Virginia, USA.
deg. N Latitude deg. W. Longitude

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5 degree (.0872rad) FOV. Spectral samples taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprising leaves was used to obtain the characteristic reflectance. The specimens sampled formed a dense canopy of lobed, sharply acuminate, glabrate green leaves. The largest, leaves measured 3 dm long and 2.5 dm wide. Specimens were growing in disturbed soils along a rock dike. The soils were dark, wet, innundated mineral soils. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

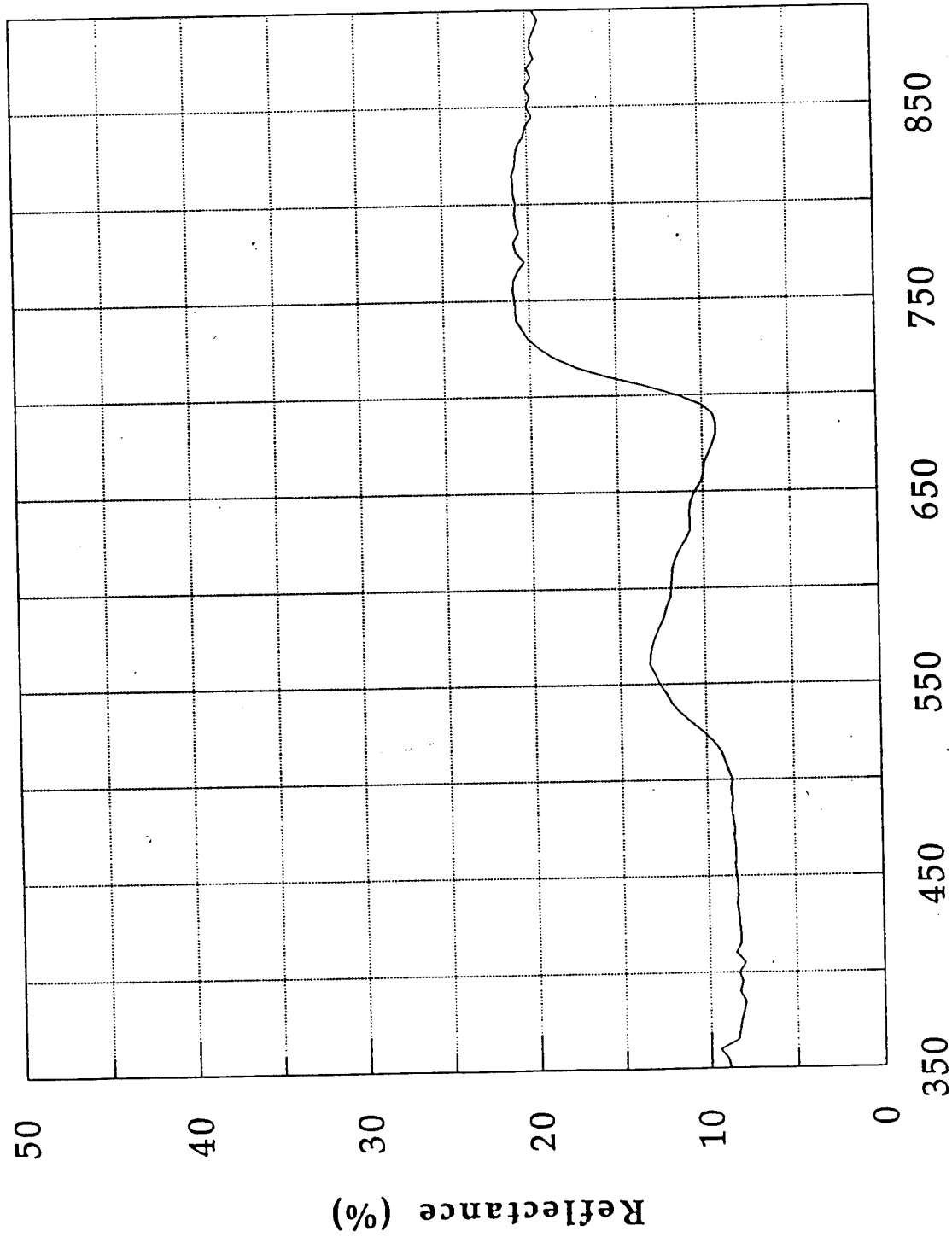
Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 100% Crown closure: 70%
Plant Height: 1.5 m Crown diameter: 2 m

Sagittaria latifolia

Big Leaf Arrowhead

Indicator Status: OBL
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Wavelength (nm)

Field Reflectance Spectra of Vegetation

Plant Name: Black Willow

Date Collected: May 27, 1994

Scientific Name: Salix nigra (Raf.)

Spectrum No. W0003

Site Location: Cedar Run III, Airlie, Fauquier Co.,
Virginia, USA.

LAT. 38° 41' deg. LONG. 77° 46' deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5 degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprised of leaves was used to obtain the characteristic reflectance. The specimens sampled formed a dense canopy of acuminate, dense light green leaves. The largest leaves measured 4 cm long and 0.5 cm wide. Specimens were growing in disturbed soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative, turgid

Crown cover in the FOV: 100% Crown closure: 80%

Plant Height: 2 m Crown diameter: <.5 m

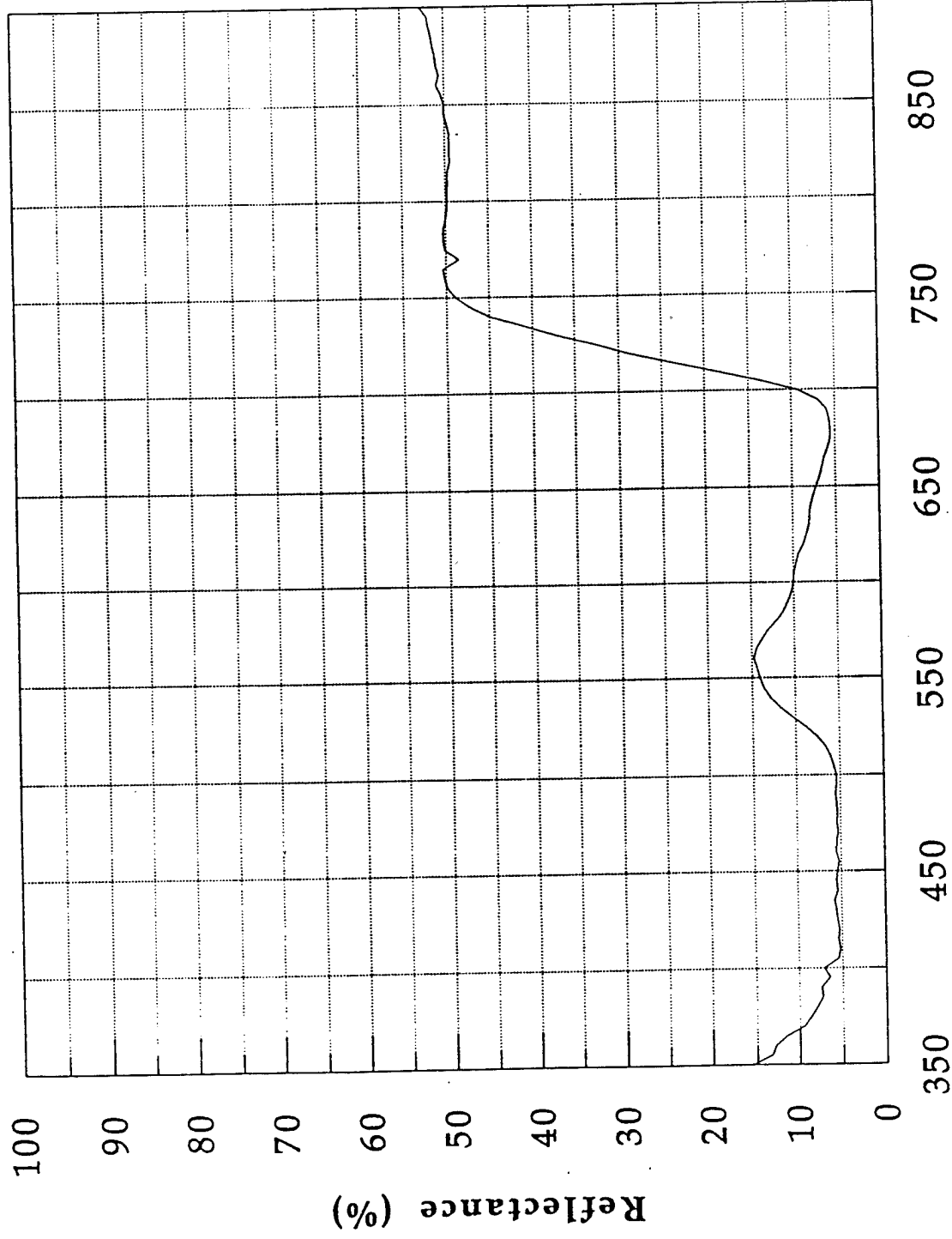
Salix nigra

Black Willow

Indicator Status: FACW

Habitat: Fresh Emergent Marsh

Cedar Run (3), Airlee, Virginia



Wavelength (nm)

Field Reflectance Spectra of Vegetation

Plant Name: Sycamore Date Collected: May 27, 1994
Scientific Name: Plantanus occidentalis (L.)
Spectrum No.W0005

Site Location: Cedar Run III, Airlie, Fauquier Co.,
Virginia, USA.
LAT. 38° 41' deg. LONG. 77° 46' deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5 degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: The *in-situ* leaf canopy was measured. A monotypic stand comprised of leaves was used to obtain the characteristic reflectance. The specimens sampled formed a dense canopy of lobed, sharply acuminate, glabrate green leaves. The largest, leaves measured 3 dm long and 2.5 dm wide. Specimens were growing in disturbed soils along a rock dike. The soils were dark, wet, innundated mineral soils. The sample was obtained in a non-tidal freshwater marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

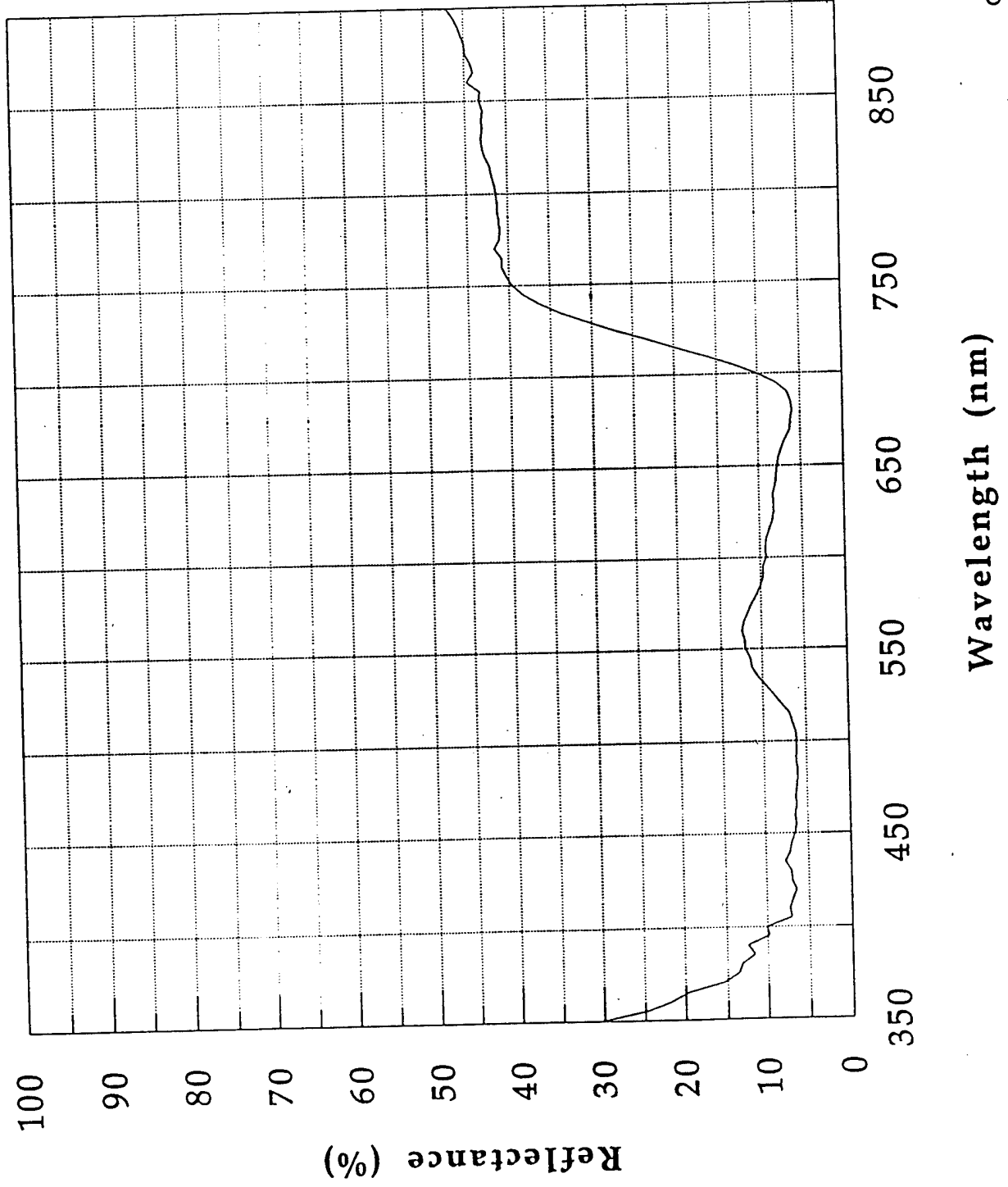
Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 100% Crown closure: 70%
Plant Height: 1.5 m Crown diameter: 2 m

Plantanus occidentalis

Sycamore

Indicator Status: FACW
Habitat: Fresh Emergent Marsh
Cedar Run (3), Airlee, Virginia



Field Reflectance Spectra of Vegetation

Plant Name: Marsh Fern
Scientific Name: *Thelypteris palustris* (L.)
Spectrum No. W0019

Date Collected: May 27, 1994

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned so fill the radiometer field-of-view.

Sample: The *in-situ* fern canopy was measured. A monotypic stand comprised of leaves and stems was used to obtain the characteristic reflectance. The specimens sampled were erect, green to yellow-green leaves divided into leaflets with rounded ends. The largest leaves measured 22 cm long and 7 cm wide. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

| | |
|--|----------------------|
| Phenological stage: vegetative, turgid | |
| Crown cover in the FOV: 100% | Crown closure: 95% |
| Plant Height: >.5m | Crown diameter: <.5m |

Compiled by: J.E. Anderson, CETEC-TD-RS

Sheet No.: VPL-W001

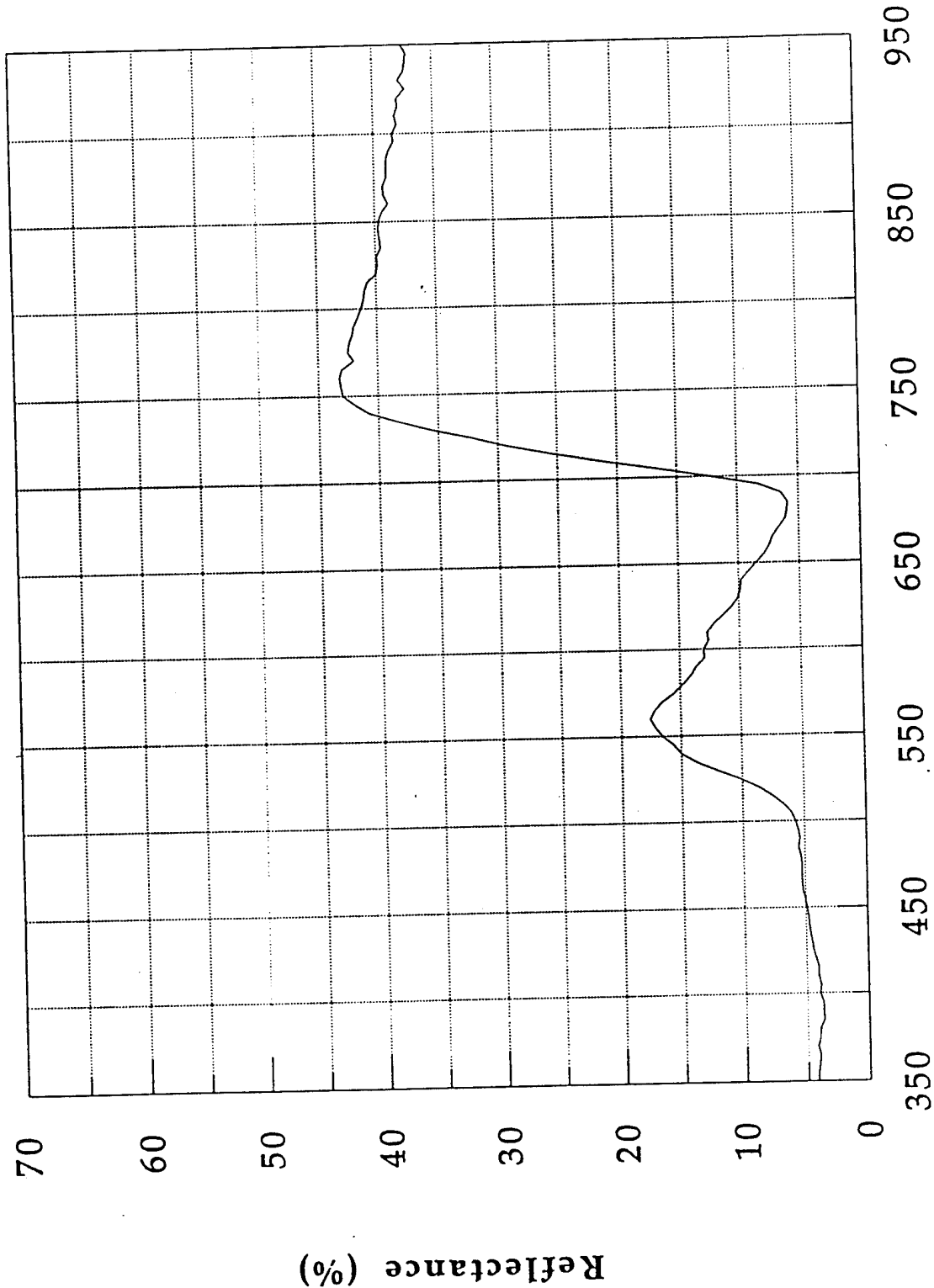
Thelpteris palustris

"Marsh Fern"

Indicator Status: FACW

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina



Wavelength (nm)

CETEC-TD-RS

Field Reflectance Spectra of Vegetation

Plant Name: Narrow-leaf Cattail Date Collected: May 27, 1994
Scientific Name: Typha angustifolia (L.)
Spectrum No.W0018

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned so fill the radiometer field-of-view.

Sample: The *in-situ* canopy was measured. A monotypic stand comprised of both leaves and stems were used to obtain the characteristic reflectance. The specimen sampled was a tall, erect, perennial herb with dark green, narrow leaves. The largest leaves measured 1.2 cm. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

| | |
|--|----------------------|
| Phenological stage: vegetative, turgid | |
| Crown cover in the FOV: 70% | Crown closure: 60% |
| Plant Height: 1m | Crown diameter: 1.2m |

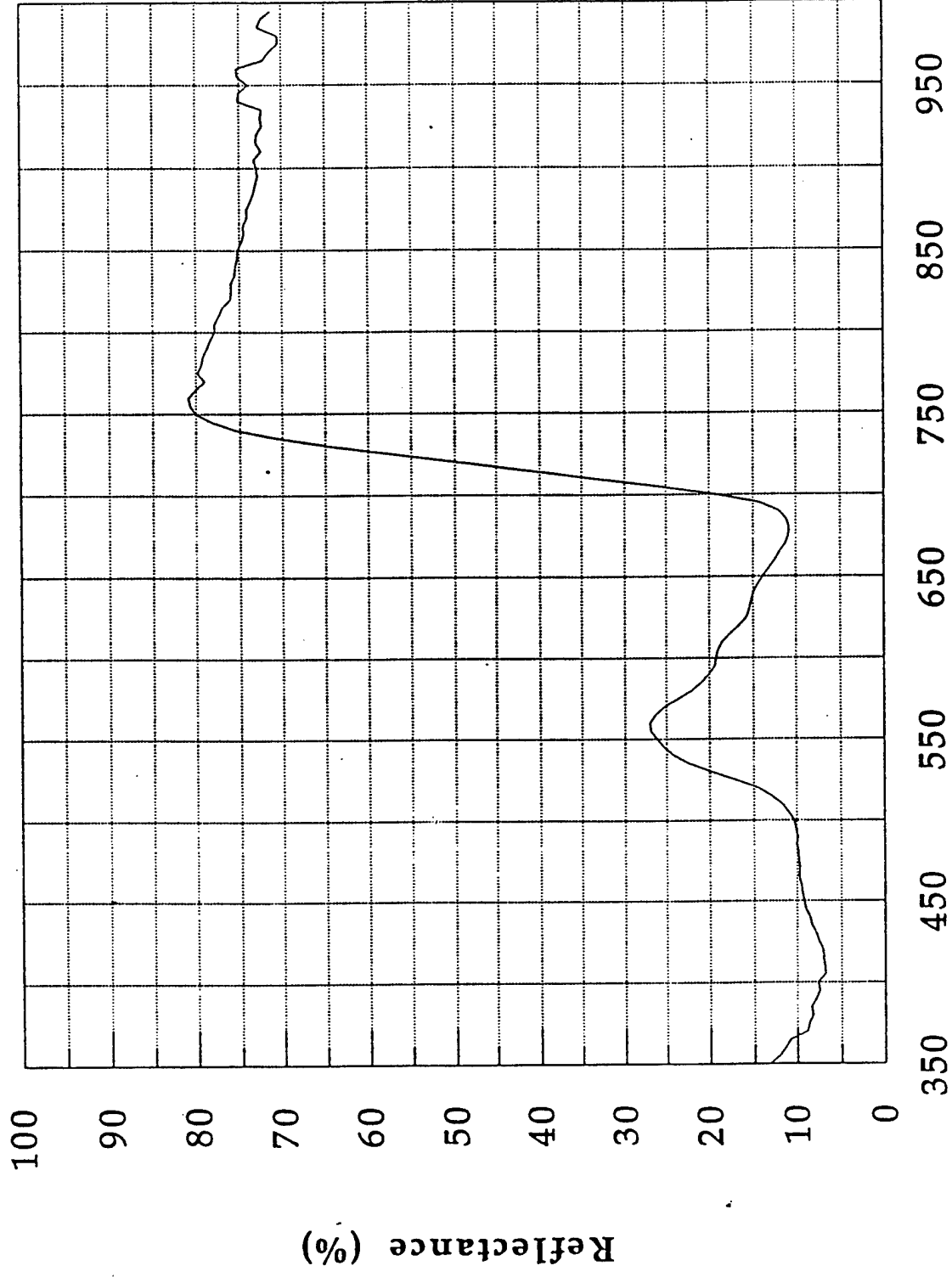
Typha angustifolia

"Narrow-Leaf Cattail"

Indicator Status: OBL

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina



Wavelength (nm)

Field Reflectance Spectra of Vegetation

Plant Name: Broad-leaf Cattail Date Collected: May 27, 1994
Scientific Name: Typha latifolia (L.)
Spectrum No. W0016

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned so fill the radiometer field-of-view.

Sample: The *in-situ* canopy was measured. A monotypic stand comprised of both leaves and stems were used to obtain the characteristic reflectance. The specimen sampled was a tall, erect, perennial herb with elongate linear basal leaves. The largest leaves measured 2.5 cm. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 80% Crown closure: 70%
Plant Height: 1.5m Crown diameter: 1m

Compiled by: J.E. Anderson, CETEC-TD-RS

Sheet No.: VT-0001

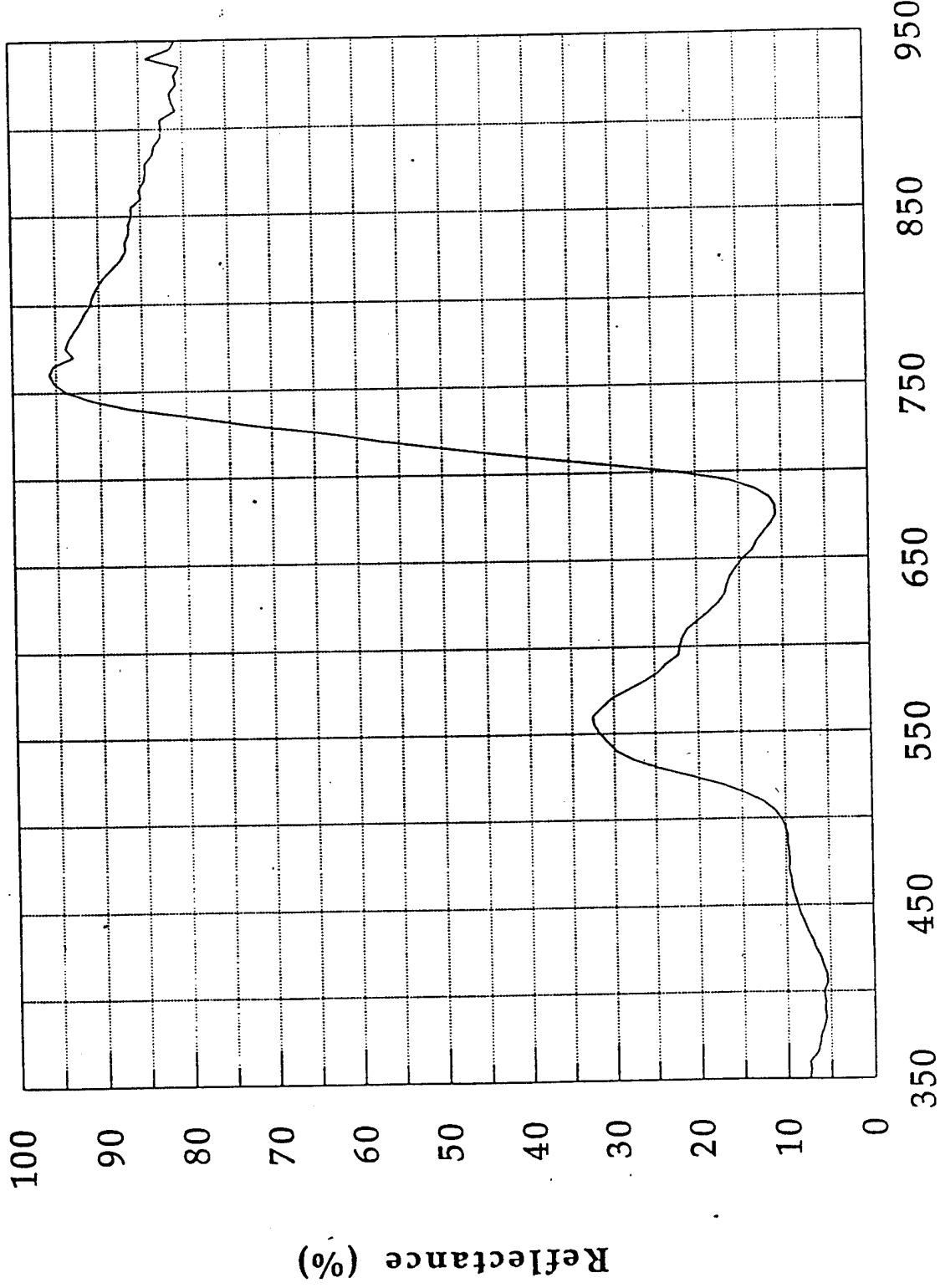
Typha latifolia

"Broad-Leaved Cattail"

Indicator Status: OBL

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina



Wavelength (nm)

Field Reflectance Spectra of Vegetation

Plant Name: Hedge bindweed Date Collected: May 27, 1994
Scientific Name: *Calystegia sepium* (L.)
Spectrum No. W0023

Site Location: Pea Island (National Wildlife Refuge), Dare Co.,
North Carolina, USA.
LAT. 36.5 deg. LONG. 75.5 deg.

Procedures:

Spectroradiometric: Analytical Spectral Devices (ASD) spectroradiometer (300 to 1100 nanometer spectral range) using a 5-degree (.0872rad) FOV. Spectral samples were taken at a nadir viewing angle under solar illumination. Reflectance standard was pressed Halon (Spectralon) and horizontally positioned with a bubble level. Plant and standard were sampled at 1 meter. Canopy was positioned to fill the radiometer field-of-view.

Sample: Vine leaf spectra was measured. A mosaic of five leaves was used to collect representative plant spectra. Leaves were triangular shaped, green, and lobed. Specimens measured 4 to 5cm in length. All specimens were growing in native soils. The soils were dark, wet, organic histisols, frequently inundated. The sample was obtained in a tidal brackish marsh. Shadow effects were minimized by taking spectra between 1000 and 1400 local solar time.

Physical & Chemical Properties:

Phenological stage: vegetative, turgid
Crown cover in the FOV: 100% Crown closure: 10%
Plant Height: N/A Crown diameter: <.25m

Compiled by: J.E. Anderson, CETEC-TD-RS

Sheet No.: VC-W001

Calystegia sepium

"Hedge Bindweed"

Indicator Status: FAC

Habitat: Brackish Tidal Marsh

Location: Pea Is., North Carolina

